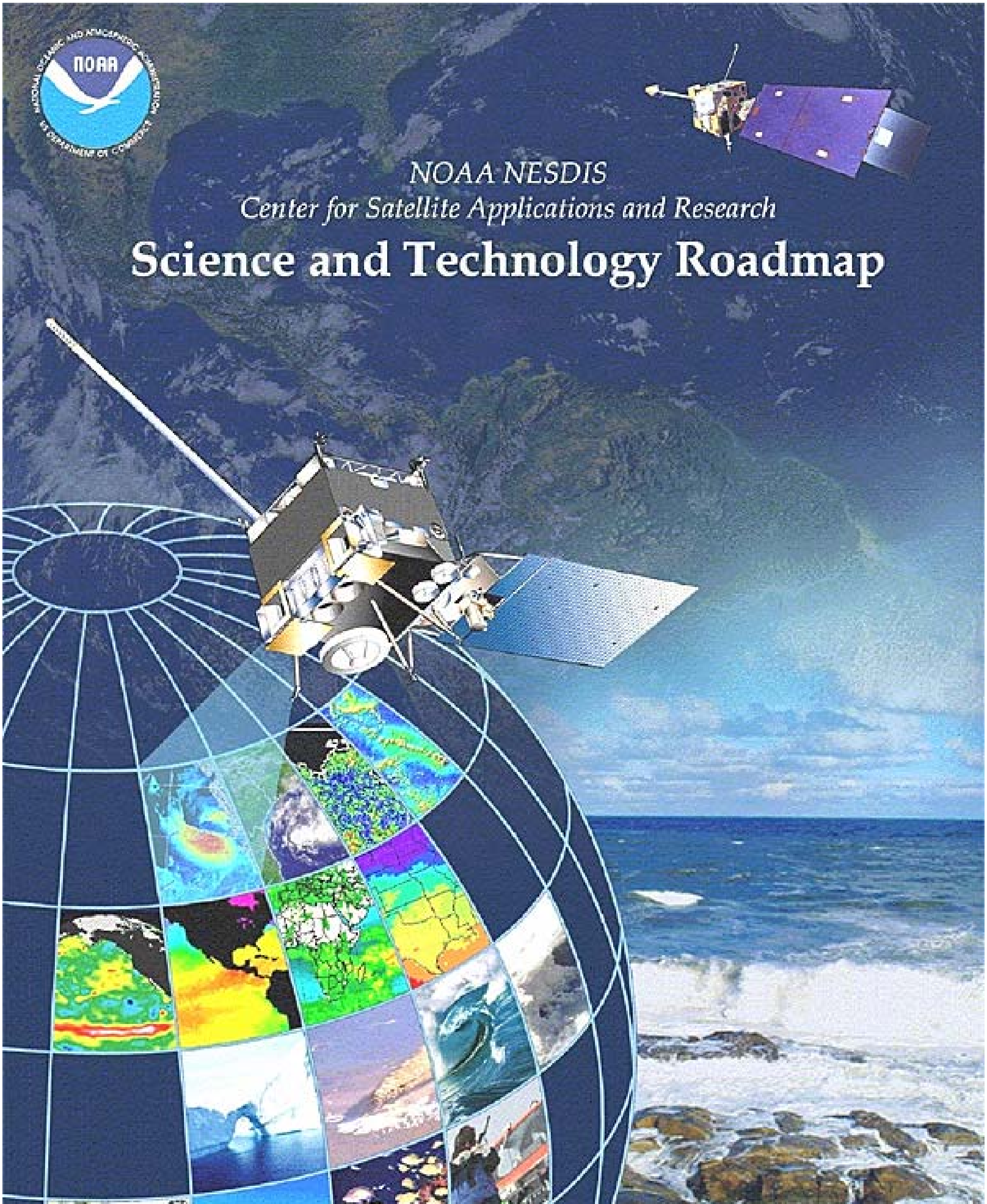
NOAA NESDIS

Center for Satellite Applications and Research

Science and Technology Roadmap



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Executive Summary

The United States invests billions of dollars annually in satellites that monitor the ever-changing environment of the Earth. The Center for Satellite Applications and Research (STAR) adds value to this investment by offering sound, satellite-based information about the Earth. This Road Map details the Center's plans to meet the challenges and opportunities of the next ten years, given expected trends in the need for environmental observations and forecasts and advances in satellite technologies.

STAR is the science arm of the National Environmental Satellite Data and Information Service (NESDIS), the component of the National Oceanic and Atmospheric Administration (NOAA) that acquires and manages the Nation's Earth-observing satellites. These satellites provide useful information about the environment for monitoring weather and climate, land, and oceans.

The mission of STAR is to create satellite-based observations of the land, atmosphere, and ocean, and transfer them from scientific research and development into routine operations. In addition, STAR offers state-of-the-art data, products, and services to decision-makers. STAR is a leader in planning future satellite observing systems to enhance the nation's ability to remotely monitor the environment. STAR also calibrates the Earth-observing instruments of all NOAA satellites to provide reliable measurements for assessing the current conditions on Earth in a timely manner, predicting changes in conditions, and studying long-term trends in the environment.

STAR's research and development program helps NOAA achieve its five strategic goals:

- **Ecosystems**—Protect, restore, and manage coastal and ocean resources through ecosystem-based management
- **Climate**—Understand climate variability and change, to enhance society's ability to plan and respond
- **Weather and Water**—Serve society's needs for weather and water information
- **Commerce and Transportation**—Support the nation's commerce with information for safe, efficient, and environmentally sound transportation
- **Critical Support**—Provide support for NOAA's mission, including its observing systems, which are a critical part of its infrastructure and essential for measuring more than 500 environmental properties.

STAR is organized into three divisions:

- The **Satellite Meteorology and Climatology Division** (SMCD) researches and develops new products that use satellite data for monitoring the global atmosphere, including weather, climate, and environmental hazards.

- The **Satellite Oceanography and Climatology Division** (SOCD) develops new products for operational ocean monitoring, from observations and measurements of ocean properties made possible by the Division's research.

- The **Cooperative Research Program** (CoRP) engages experts in the academic community to realize the vision of STAR, through a unique partnership between STAR and academia. Each of three branches of CoRP—consisting of government scientists—is collocated with a Cooperative Institute managed by a university partner. CoRP research is also supported by two other universities.

STAR's research and development program for the next five years is driven by NOAA's strategic goals, national and international programs in which NOAA participates, emerging trends in satellite technology, and most of all, the needs of users.

For NOAA's **Ecosystems** Goal, STAR provides the tools and data for people to monitor, assess, and predict the health of ecosystems in the Nation and its regions, using NOAA's global system to observe the environment.

NOAA's mission for the 21st century includes a new **Climate** Goal: to "understand climate variability and change to enhance society's ability to plan and respond." NOAA has two strategies for achieving this goal:

1. Improve the quality and quantity of climate observations, analyses, interpretations, and archives by maintaining a consistent climate record, and improve the ability to determine why climate changes are taking place.
2. Improve the understanding of the forces bringing about climate change by examining human-induced increases in atmospheric gases and dusts.

STAR's roles are to construct highly accurate, satellite-based climatic records of properties of the atmosphere, ocean, and land, and to develop satellite-based techniques for monitoring greenhouse gases.

STAR helps NOAA to achieve its **Weather and Water** Goal:

- To increase the lead-time and accuracy of weather forecasts and warnings, ocean forecasts, and river forecasts
- To improve the prediction of the onset, duration, and impacts of severe weather, river flooding, and severe ocean conditions.

STAR also assists NOAA's emerging air quality forecast program by measuring aerosols and air pollution from satellites.

STAR contributes to NOAA's **Commerce and Transportation** Goal by tailoring satellite-based products for air transportation (the Aviation Weather program) and marine transportation (the Marine Weather and Sea Ice programs).

A number of important trends in instrument technologies will be implemented in the next generation of operational satellites, including the following:

- *Hyperspectral* instruments for sounding and imaging the Earth's environment with greater detail than ever before possible will measure the atmosphere, land, and oceans with unprecedented information content, frequency, and timeliness.
- Radar, lidar, and microwave instruments will measure the **vertical structure of the atmosphere,** including temperature, moisture, clouds, precipitation, and aerosols.
- Radar instruments will measure **surface properties of the ocean** directly and in fine spatial detail, providing information on winds, water roughness, sea level, sea ice, and ocean currents.
- New instruments will provide the first space-based information on ocean salinity, soil moisture, and aerosol properties, and will establish NOAA as an observer of ocean color, solar radiation, and the radiation budget of Earth, now observed only by research satellites of other agencies.

Responding to user requirements and satellite technologies, STAR divides its scientific research among 38 projects that support NOAA's Strategic Goals. Some science projects deliver products that meet the needs of users directly. Other projects deliver new satellite observations into computer models that simulate and predict the environment, through the efforts of the Joint Center for Satellite Data Assimilation, a partnership of NOAA, the National Aeronautics and Space Administration (NASA), and the Department of Defense. The Joint Center helps STAR to satisfy requirements for products that users need.

STAR will create new products for monitoring atmospheric, oceanic, and environmental hazards; enhance NOAA's infrastructure for remote sensing; reduce the risk of launching new, untested, and very expensive satellites and sensors; expand its support to users (for example, expanding the NOAA CoastWatch Program into a global OceanWatch); and train users of STAR products and applications.

The achievement of STAR's goals will be facilitated by a dramatic increase in observing capability over the next five years; by a world-class team of government and contract scientists and visiting scientists; and by advances in computing and communications technologies. Potential constraints include insufficient computing power; limited scientific progress in some new instrument areas; a need for more "ground truth" measurements of the land, the sea, and the air; and anticipated losses of senior scientists in the workforce due to retirement.

1 Introduction

The purpose of this **"Road Map"** is to "map" the science and technology activities of the Center for Satellite Applications and Research (STAR) to the Strategic Plan of the National Oceanic and Atmospheric Administration (NOAA) for the next five to twenty years. The Center is part of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS). This Road Map, a necessary step in the planning process, begins with guidelines in the NOAA Strategic Plan and the NOAA Research Plan. The STAR Road Map frames the road maps of STAR's three Divisions as well as the Research Project Plans (RPP) of the science projects. The STAR planning pyramid in Figure 1 (below) links planning at STAR to the various levels of planning in NOAA.

Figure 1. The STAR planning pyramid

The Road Map is organized according to the NOAA Strategic Goals. STAR activities for the next five years are linked to each NOAA Strategic goal. STAR contains three divisions, each of which has its own road map. The Division Road Maps outline science projects that support the Center's performance goals and that describe significant milestones. The STAR Road Map will be updated every three to five years or more often if necessary.

Another pyramid in Figure 2 illustrates (along with Figure 1) how the components of the STAR Road Map are related to NOAA-wide goals, priorities, and measures of performance. In addition to mapping STAR activities to the NOAA Strategic Plan, this Road Map:

- Informs stakeholders how STAR will address their requirements

- Shows relationships among research activities

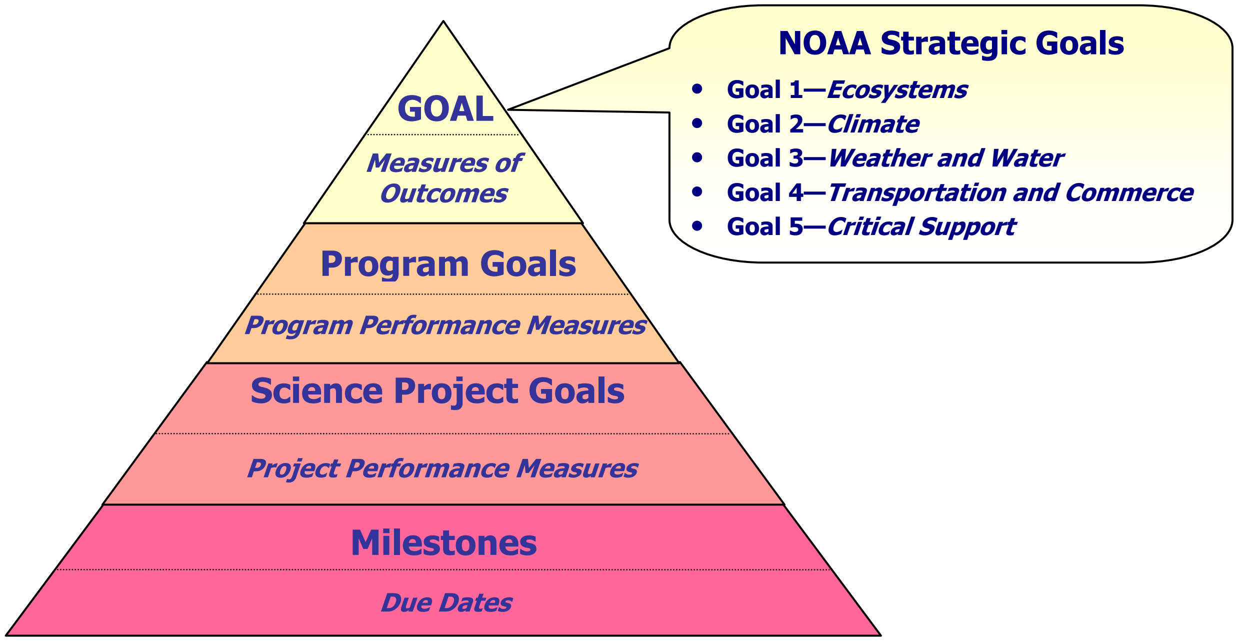


Figure 2. Relation of goals, performance measures, and milestones

- Identifies key technologies and skills in which STAR has competitive advantages.

Using this Road Map, STAR will be able to:

- Identify future technologies that STAR may apply to create improved scientific products
- Locate gaps in research, technology, and exploration
- Ascertain the best or most realistic set of targets
- Prioritize options for spending and investment by the Center
- Put its team members in contact with colleagues in other NOAA programs and other agencies
- Identify the best solutions to fulfill requirements of users of STAR products, permitting growth beyond the possibilities allowed by existing products and services
- Clarify alternatives, allowing the STAR team to recognize and act on events that require a change in direction — *planning for the unexpected*
- Inform users of future enhanced products.

2 Background

The Center for Satellite Applications and Research (STAR) is an operations-driven research and development center, attuned to the needs of the nation's users of satellite data products. STAR conducts diverse research within the arena of satellite remote sensing, including the study of atmospheric, oceanic, and land processes. NOAA maintains operational satellites and produces data and products from those satellites. STAR participates in the life cycle of all operational NOAA satellites from beginning to end—from defining the initial requirements for a satellite mission, through calibration and application of the data, to development of products from the data, to final archiving, and even reprocessing of data as needed. STAR also works with data from non-NOAA satellites as well, for purposes of research, to transfer capabilities into NOAA, and to augment the data streams that NOAA manages. This process is given in Figure 3.

Figure 3. STAR activities through the life cycle of a satellite mission

To ensure continuity, NOAA plans for new satellites to replace old satellites and to incorporate breakthroughs in technology. During the design phase of new satellites, STAR provides expert consultation on the trade-offs in cost and risk for new instruments on the satellites.

The longer a satellite operates, the greater the risk of an instrument degrading or failing. STAR continually calibrates and validates data from NOAA's satellites to ensure the data are accurate, reliable, and representative. This eliminates the need for every user to perform time-consuming and complicated adjustments before using the information. STAR offers significant value to the community of satellite users through its calibration and validation role alone. STAR adds significant value to satellite data—whether raw data or products—by accomplishing this quality control step cost-effectively in a single office prior to distribution. As a result, decisions that are based on STAR products are much more sound.

STAR investigates how to develop satellite data sets that can be used in the following ways:

Assess the current conditions on the Earth in a timely manner

- Predict changes in the current conditions

- Study long-term trends in the environment

These data sets are used by scientists worldwide for the study of the Earth and its environment.

STAR develops products for the operational community of users—including commercial and government users. This information helps the public and private sectors make better choices that benefit their lives and businesses.

2.1 Vision and Mission of STAR

STAR Vision

To advance remote sensing science and technology to better inform the American public and safeguard the environment.

STAR Mission

To transfer satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine operations, and offer state-of-the-art data, products, and services to decision-makers.

Figure 4. STAR Vision and Mission

A complete description of STAR's mission and what it does can be found at its web site: http://www.orbit.nesdis.noaa.gov/star/index.php.

2.2 STAR Values

Professional staff and government, contractor, and university employees are critical assets; their diverse talents are the main reasons for STAR's success. The Center maintains a culture that encourages creativity, initiative, and collaboration from the staff. It has professional administrative support staff and an Information Technology (IT) support team that are essential to this success.

STAR engages in research and development (R & D) according to four principles:

- ***Create: Be New.*** Generate fundamentally different ideas, instruments, techniques, or prototypes. This leads to **concepts.**
- ***Produce: Be First.*** Complete and introduce into the knowledge base a theory, scientific tool, product, or process that is very different from existing ideas or technologies. This leads to **products.**

- ***Enhance: Be Better.*** Incrementally improve or standardize an existing model, technique, product, process, or technology. This leads to **enhancements.**
- ***Master: Be Sustainable***. Generate incremental advances in knowledge, in order to master or extend existing ideas, techniques, or technologies. This leads to **mastery.**

3 Trends and Drivers

STAR's strategy for improving remote-sensing systems and their use is to:

- Contribute to the decisions that NESDIS makes about systems, programs, and applications
- Leverage more resources by maintaining and enhancing outside collaborations
- Foster strong working relationships with the entire user community both locally and globally
- Invest in the future by allocating resources to high payoff opportunities.

To meet the challenges in satellite remote sensing, STAR must be aware of—and plan for—changing trends and drivers.

3.1 Customer Requirements

STAR supports the NOAA mission by providing the following scientific services to the users of NOAA's satellites:

- Planning new satellites and sensors that monitor the environment
- Collecting and processing data from environmental satellites
- Building quality and reliability into NOAA satellite data and services
- Providing satellite products and services that NOAA and others can use to accomplish their mission

NOAA's mission includes performing public services that involve the earth's atmosphere, land, and ocean. These include providing information, forecasts, advisories, and warnings; keeping official records; and regulating activities that impact the environment. STAR develops the means to obtain the necessary information from satellite data, and enables NOAA to deliver these public services.

Since NOAA collaborates with scientific organizations all over the world, STAR supports scientific collaboration in satellite information and use. STAR shares its research and data with other government offices and with international scientific partners.

3.2 Advancing Technology

In the next 15 years, NOAA will develop, implement, and collaborate on a series of new satellite programs: the Initial Joint Polar-orbiting Satellite system (IJPS) with Europe, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), and the Geostationary Operational Environmental Satellite Series R (GOES-R). NOAA will also help integrate a global system of environmental observation data, which will require integration of data from international satellites and other Earth observations. This worldwide program of shared environmental data and resources is called the Global Earth Observation System of Systems (GEOSS). Satellite data will be the largest source of data by volume in this global system.

New satellites and satellite instruments lead to improvements for users. STAR plays a very important role in making these improvements possible. STAR ensures that the data derived from the next–generation polar-orbiting satellites (such as NPOESS) and future geostationary satellites (GOES-R) will provide the best possible value to the users of this nation's investment. The calibration and validation teams lead the way in enabling the entire network of satellites to provide the best information.

As each new mission becomes operational, STAR's world-class scientists continue to develop new practical applications from cutting-edge research in order to meet or exceed the requirements of users. As the satellites become operational, the improved monitoring and forecasting of the environment will allow better decisions to be made at lower cost. To put this advance in perspective, the impact of weather on the U.S. economy is now about $3 trillion.

Numerous initiatives in the Earth-observing scientific community will significantly impact NOAA and STAR programs. NOAA and its global partners are deploying several new observing platforms and sensors. User demands for satellite data products are growing rapidly as climate, ocean, and land-use issues gain world attention and as demand increases for greater precision and accuracy of measurements. Scientists around the world realize that there is a need to build a comprehensive and integrated system for Earth observation. Because the volume and coverage of satellite data are growing exponentially and the ways to use the data have diversified, NESDIS is expanding its ability to process and archive data and to distribute it faster to more users. That means that STAR must be creative in support of these demands on NESDIS.

In the last decade as the number of sensors and telecommunications channels has exploded, remote sensing of the environment has undergone rapid change. While the number of sensors grew nearly linearly until about 1992, their complexity has increased since then, due to the introduction of "hyperspectral" instruments. With these new instruments, some people predict that the volume of data will grow by ten orders of magnitude in the next ten years. Figure 5 illustrates the impact of this data explosion.

		Today	2008-2016	2020+
Satellites	*Polar-Orbiting*	3	3	3
	Geostationary	2	2	2
	Non-NOAA	5	12	14
Sensors		30	45	70
Spatial Resolution		4 km	1 km	0.4 km
Temporal Resolution		30 min	15 min	5 min

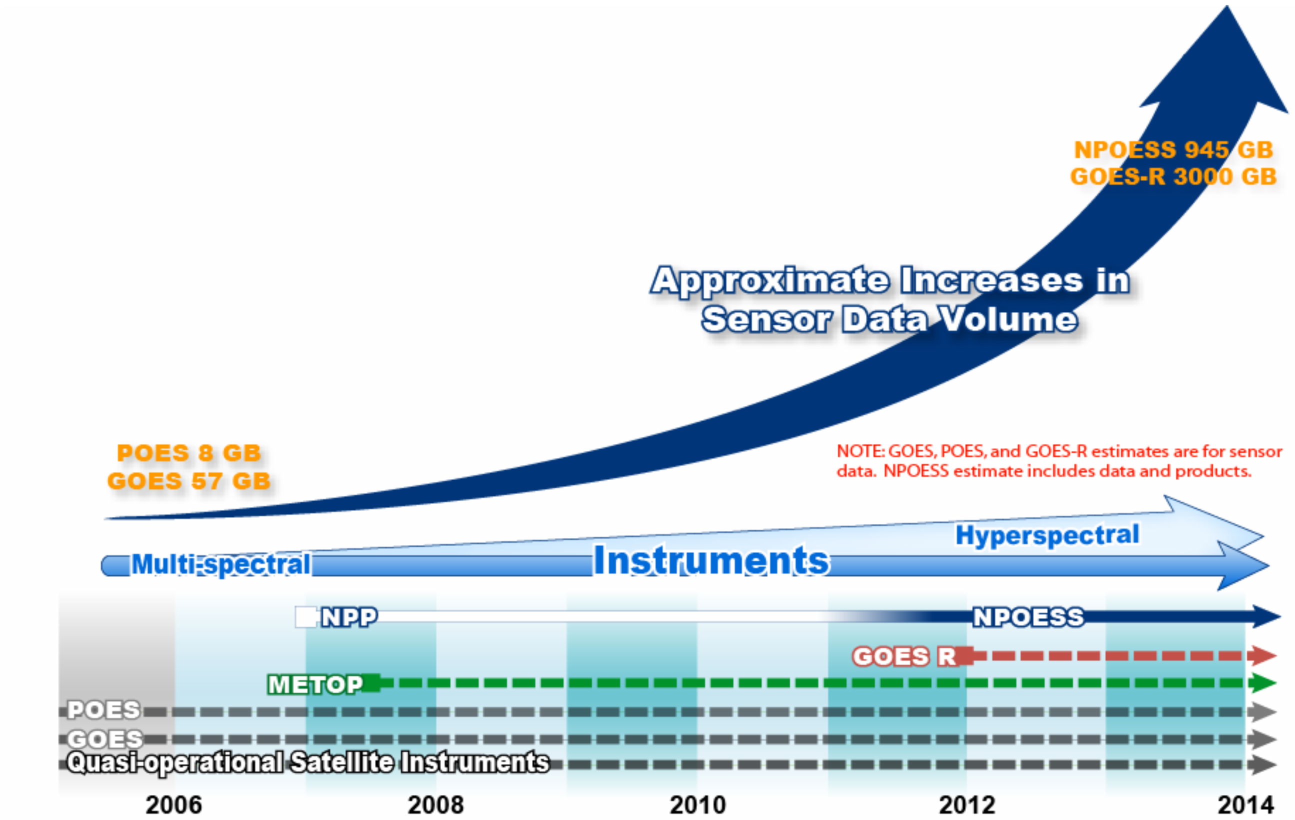


Figure 5. The amount of data from satellites will explode in coming years

As noted in the table, STAR will exploit increasingly finer resolution data in space, time, and wavelength. The ever-increasing detail allows new observations of atmospheric physics and the physics and biology of the ocean on scales never before observed. STAR will help prepare the United States to fully exploit this new information. As the capability of communications and computing increased dramatically, STAR partnered with international scientists who continue to improve the monitoring and use of such data.

3.3 Collaboration with Partners and Users

NOAA is changing the way it goes about the business of using satellites. Instead of having individual satellites serve the needs of individual organizations, government agencies and international organizations now collaborate to define requirements for the satellite systems of the future. Future satellites will meet global requirements for information on the Earth's environment—its atmosphere, land, and oceans. Nations are pooling their resources to produce better satellite systems with an increasing number of enhanced instruments. These capabilities will improve understanding of the Earth for the benefit of the global village.

The new approach to satellite design considers individual satellites a part of the global observing system and as a component of a particular satellite system. For example, NOAA is working with the European Community to introduce Meteorological Operations Platform (Metop), the new European satellite. Metop will serve the entire globe by providing data to NPOESS. Benefits of this collaboration include increased observing capacities, the reduction of data redundancy, and the development of scientific relationships.

STAR is enjoining national and international research partners to explore science with this new approach and to use these enhanced assets for remote-sensing. The following challenges will be addressed:

- Maintaining continuity of observations
- Resolving differences between satellites and systems
- Processing and distributing vastly greater volumes of data
- Developing more flexible strategies for managing the data and its conversion into products and applications
- Providing timely access to satellite information to a broad range of users and decision-makers who have diverse needs for information
- Exploring new instrumentation and new data in order to generate new products or services

The responsibilities of NESDIS for the operation and use of the new Polar-orbiting Environmental Satellite (POES) and geostationary (GOES) satellite systems will be very different than they are now. Private contractors will be responsible for much of the system development and operation of POES and GOES. However, NESDIS offices and STAR will retain important oversight for development, calibration, validation, and quality assurance during all phases of deployment and operation for both programs. STAR will be responsible for providing recommended algorithms and collaboration for GOES-R contractors over the life cycle of the satellite system. STAR algorithms will be encoded in operational software that will automatically calibrate, produce, and validate GOES-R data. Other STAR research will bridge some of the inter-satellite gaps that can result from using data from different satellites or sensors.

3.4 Global Monitoring

NOAA operates under the premise that “Better monitoring of the earth’s environment produces more informed decisions.” NOAA is continually looking for better ways to monitor the Earth and its environment.

NOAA is leading international programs that will further understanding of the Earth’s environment and is developing products that will serve the global community. Satellite meteorology is a global enterprise demanding coordinated, international, science-based research and development. This collaboration extends to new areas such as satellite oceanography. The greatest benefits obtainable from global satellite systems result from focused working groups that transcend political boundaries, under the auspices of inter-governmental protocols.

STAR leads the effort to expand national and international remote sensing monitoring capabilities. Along with partners in the National Aeronautics and Space Administration (NASA) and the Department of Defense, STAR participates in and advises teams that plan the next generation of polar-orbiting satellites. In several instances, STAR scientists either serve as chair or participate as members of these teams. STAR also chairs and participates in the GOES Technical Advisory Committees that guide the new imaging and sounding sensors and new ocean sensors on the geostationary satellites.

The Center is active in the Coordinating Group for Meteorological Satellites, where the international community sets communications formats, shares science algorithms, and prepares strategies to fill gaps in the global observing system. STAR scientists work with the World Meteorological Organization (WMO) to define a future global observing system that combines the present research and operational satellites. Finally, as NESDIS is a leader on the Committee on Earth Observation Satellites (CEOS), STAR helps NESDIS to coordinate international programs of Earth observation.

STAR fosters international partnerships with organizations all over the world that focus on monitoring Earth with satellite data. Examples include the European Space Agency (ESA) and European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), as well as space agencies and science organizations in India, Japan, China, Russia, and Korea.

While NOAA's leadership in GEOSS is clearly in the Nation's interest, it also assists international partners. Satellite systems and instruments from national agencies in many countries and from international agencies will be integrated in GEOSS, a multinational initiative to establish a comprehensive, coordinated, and sustained Earth observation system. GEOSS participants recognize that the global community must act together and share information. Together, all participants must establish standards for the quality, formats, and exchange of data; avoid redundancy, and determine future needs for global monitoring.

A coordinated global system of Earth observations will provide the tools to make national and global forecasts of air quality, to know in advance when droughts might occur and for how long, and to predict the outbreak of deadly diseases by tracking the factors that contribute to their spread in the environment. The availability of integrated, multi-purpose observations will transform the way society interacts with its environment, and provide significant benefits through better health and well-being, better management of the environment, and more economic growth.

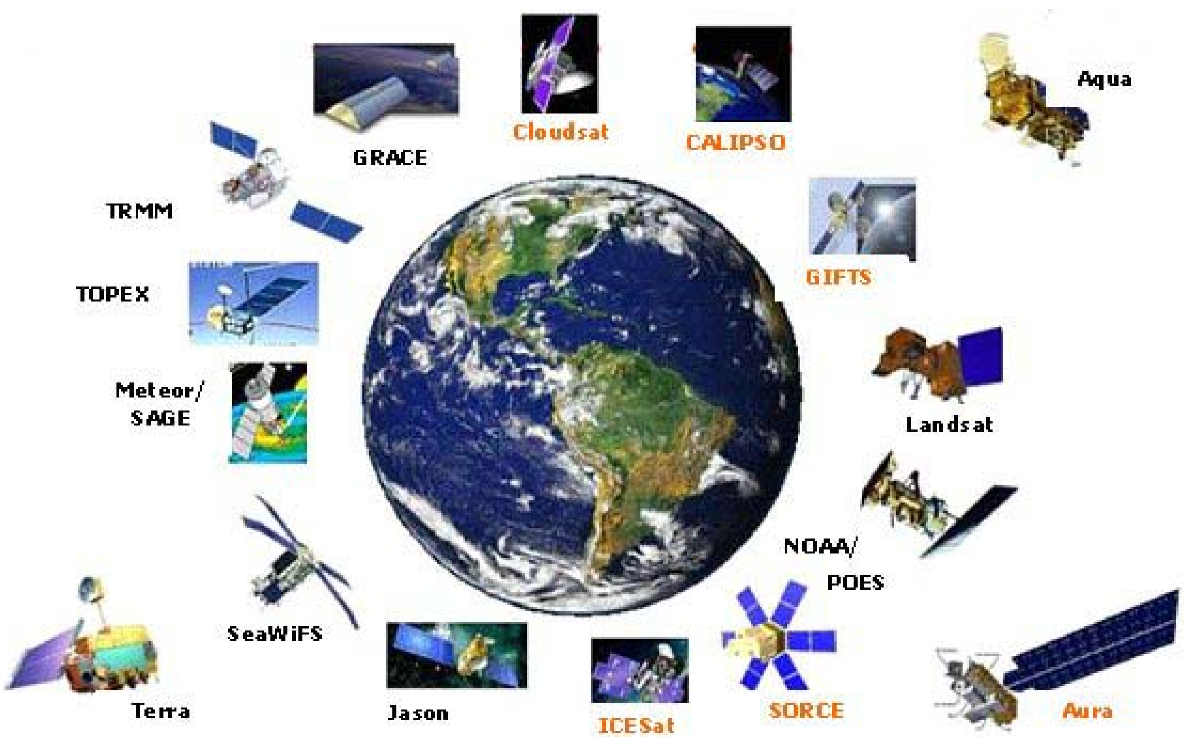


Figure 6. Global Earth Observations

3.5 Predicting Changes in the Earth's Environment

The essence of NOAA's mission is to "understand and predict changes in the Earth's environment." Within that mission, NOAA provides the American public with routine products and services that result from a better understanding of the Earth's environment and from better technology. These products and services enable the nation to make better decisions related to environmental changes. Furthermore, NOAA works with other nations and with scientists all over the world to share information and techniques.

The health and economic effects of extreme weather and poor atmospheric conditions are primary drivers for NOAA's warning and forecasting responsibilities. Stakeholders increasingly expect more lead time and accuracy in weather forecasts in order to support disaster services, search and rescue, and military operations. NOAA needs more capability to monitor atmospheric, land, and ocean properties related to public health and safety, such as atmospheric pollutants, harmful algal blooms, and West Nile virus. Since STAR has created products to monitor such phenomena, STAR is empowering NOAA to meet its responsibilities.

3.6 NOAA's Strategic Plan

NOAA's Strategic Plan explains how it will respond to mandates from Congress and will prioritize its goals for five years. The Strategic Plan provides priorities and strategies to guide mission requirements in each of NOAA's strategic goals:

- **Ecosystems**—Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management
- **Climate**—Understand climate variability and change to enhance society's ability to plan and respond
- **Weather and Water**—Serve society's needs for weather and water information
- **Commerce and Transportation**—Support the nation's commerce with information for safe, efficient, and environmentally sound transportation
- **Critical Support**—Provide support for NOAA's mission, including its observing systems, which are critical for obtaining measurements of more than 500 environmental properties

In its Five-Year research plan, NOAA highlighted the importance of developing an integrated observing system on both local and global scales. NOAA also produces a twenty-year "Research Vision" that provides the "big picture" of where NOAA will go and the role that research will play. At the annual meeting of the American Meteorological Society in January 2005, the NOAA Administrator stressed the following areas as NOAA priorities:

- Early warning for temperature, humidity, vegetation, and soil moisture
- Air quality—wet deposition trends, composition of aerosols, global distribution of ozone, and forest fires
- Sustainable agriculture practices
- Programs to acquire satellites

STAR has developed products for monitoring conditions in the first two categories, and is an important partner in determining which technologies are flown on new satellites, in the fourth category.

3.7 Mandates for STAR's Mission

The STAR strategy for meeting the challenge of improving remote-sensing systems and their utilization is to:

- Contribute to the NESDIS decision making process regarding systems, programs, and applications
- Leverage resources by maintaining and enhancing outside links and collaborations
- Foster strong working relationships with the entire user community, locally and globally
- Invest in the future through resource allocation to risk-managed, high payoff opportunities.

The general umbrella under which NESDIS and STAR perform their research mission is found in the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554). Section 515 of this Act provides a legal basis for NOAA research. The following table illustrates several more mandates for specific areas of STAR's mission:

Legislation	Mandate
Ecosystems	
National Environmental Policy Act of 1971 (42 U.S. Code [USC] 4321 et seq.)	Mandated environmental impact statements, including investigations of protected species
Marine Mammal Protection Act of 1973 (16 USC 1361-1407)	Identified protected species
Endangered Species Act of 1973 (16 USC 1531-1544)	Established procedures to declare species as protected
Marine Protection, Research and Sanctuaries Act (Public Law [PL] 104-283)	Established two national centers: National Centers for Coastal Ocean Science and Center for Coastal Monitoring and Assessment
Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1801-1, 1882)	Mandated protection and restoration of critical habitat
*Harmful Algal Bloom and Hypoxia Research and Control Act of 1988 (*33 USC 1121 et seq.)	Mandated monitoring of algae and response to bloom events
Climate	
Global Change Research Act of 1990 (PL 101-606, 15 USC 2921 et. seq.)	Established the U.S. Global Change Research Program, managed by NOAA; now the Climate Change Science Program
Clean Air Act Amendments of 1990 (PL 95-95)	Requires NOAA to "…continue programs of research, technology, and monitoring of the phenomena of the stratosphere for the purpose of understanding the physics and chemistry of the stratosphere and for early detection of potentially **harmful changes in the ozone** in the stratosphere…." Further, NOAA is required to report "…the current average tropospheric concentration of chlorine and bromine and the level of stratospheric **ozone depletion**."
U.S. Climate Change Science Program (CCSP)	Set up by Executive Action in 2002, as a merger of the U.S. Global Change Research Program with several new programs; brought together 13 distinct federal agencies
U.S. Carbon Cycle Science Plan (USGCRP, 1999) and associated implementation plans	Defined five goals—three that pertain directly to NOAA expertise: "Quantify and understand the Northern Hemisphere terrestrial carbon sink", "Quantify and understand the uptake of anthropogenic CO2 in the ocean", and "Provide greatly improved projections of future atmospheric concentrations of CO2." NOAA's Climate Forcing Program is designed to meet those goals

Legislation	Mandate
Weather and Water	
Organic Act of October 1, 1890	Created the National Weather Bureau and established its mission to provide weather and water information to the nation
Inland Flood Forecasting and Warning System Act of 2002 (15 USC Ch 9 (PL 107-253)	Set up a system for monitoring rainfall and warning of river flooding
U.S. Code Title 15, Chapter 9, Section 313	"The Secretary of Commerce shall have charge of the **forecasting of weather, the issue of storm warnings,**…for the benefit of agriculture, commerce, and navigation,…and the collection and transmission of marine intelligence for the benefit of commerce and navigation,…the distribution of meteorological information in the interests of agriculture and commerce, and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties."
Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended (PL 106-390), 42 USC, Ch. 68	Set up a Federal Response Plan (FRP) of the Federal Emergency Management Agency (FEMA), in 1999.The FRP tasks the Department of Commerce with acquiring and disseminating weather data, forecasts, and emergency information, providing information on natural resources, predicting pollution movement, and providing information on meteorological, hydrological, ice, and oceanographic conditions
Federal Plan for Meteorological Services and Supporting Research of 1963 (PL 87-843)	Set up the Federal Coordinator for Meteorology FCM-P1-2002, a mandate for governmental research and development programs that directly improve meteorological services in an effective and efficient manner
U.S. Weather Research Program Authorization Act	Mandates that the U.S. Weather Research Program (USWRP) accelerate forecast improvements of high-impact weather and facilitate full use of advanced weather information
Air Quality	
Energy Policy Act of 2002, Forecasts and Warnings; appropriations in later years in H.R. 4 (with Senate Amendment, S. 517), Part II, Section 1383:	Mandates NOAA to issue air quality forecasts and perform regional air quality assessments
Clean Air Act Amendments of 1990, "Great Waters" (Section 112[m], Title III) *Atmospheric Deposition to Great Lakes and Coastal Waters*	Mandates NOAA to identify and assess the extent of deposition of atmospheric pollutants to significant bodies of water
Clean Air Act Amendments of 1990, "Ecosystem Research" (Section 901[e], Title IX)	Mandates NOAA to conduct a research program to improve understanding of the short-term and long-term causes, effects, and trends of damage from air pollutants on ecosystems
Memorandum of Understanding between NOAA and the Environmental Protection Agency (EPA), May 2003	Mandates NOAA and EPA to collaborate on air quality research, and on forecasting of air quality; NOAA deliverables include improved air quality forecast models and forecast guidance
Oceans and Coasts	
USC Title 33, Chapter 17, Section 883j, and "Ocean Satellite Data"	Mandates NOAA to take such actions, including the sponsorship of applied research, as may be necessary to ensure the **future availability and usefulness of ocean satellite data to the maritime community**
The Oceans Act of 2000	Called for a new national ocean policy; created U.S. Commission on Ocean Policy, which published ***An Ocean Blueprint for the 21st Century***
National Marine Sanctuaries Act (PL 106-513; 16 USC: Conservation, Chapter 32: Marine Sanctuaries, Sec. 1431)	Set up the Sustainable Seas Experiment

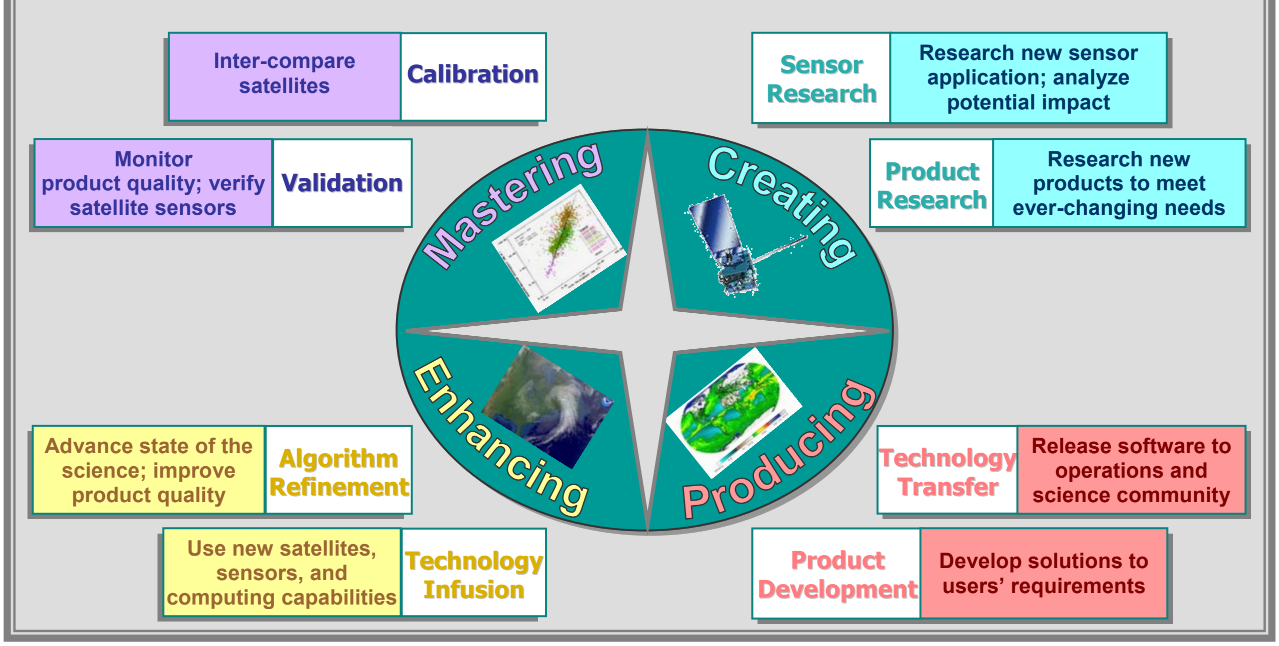
Commerce and Transportation	
USC Title 49—*Transportation, Subtitle vii—Aviation Programs, Part A—Air Commerce and Safety, Subpart iii—Safety, Chapter 447—Safety Regulation, Sec. 44720*	Established weather and safety regulations

NOAA's responsibilities are also described in Cooperative Agreements and Operational Plans developed with partners of NOAA. These are listed in Appendix B. Several agreements of inter-agency cooperation assign NOAA the responsibility for collecting climate, weather, and snow data and providing river level, flood forecasts and flash-flood warnings.

4 Current Research and Capabilities

There are four phases of the life cycle of satellite hardware, data, and products. At the *Creating* stage of development of products and systems, STAR works with the users to identify their requirements and the important science questions. STAR scientists then research new sensor technology, products, and applications to meet the requirements. In the *Producing* phase, STAR develops and tests products that meet the customer's requirements. Products that prove useful are transferred to operations for customer use. Once a product is operational, customer feedback guides the selection of products for *Enhancing*. Refining the formulas used to produce operational products and combining data from other sensors are two techniques used to improve the products. In the *Mastering* phase, STAR shares the science with others to promote creative thinking about methods to use satellite data to obtain better information about the Earth and its environment. Finally, quality and excellence are built into routine methods for processing data.

Figure 7: Functions and Capabilities Provided by STAR



To optimize its efforts, STAR is divided into three divisions: the Satellite Meteorology and Climatology Division, the Satellite Oceanography and Climatology Division, and the Cooperative Research Program.

4.1 The Satellite Meteorology and Climatology Division

An understanding of processes on land and in the atmosphere is a key to good stewardship. The Satellite Meteorology and Climatology Division (SMCD) leads NOAA's research efforts in obtaining this knowledge through remote sensing from satellites. The SMCD conducts research into meteorological parameters and phenomena, climate processes, and characterization of the land. This Division monitors many different atmospheric hazards and calibrates and validates satellite data for the highest-quality climate records.

Satellite Meteorology and Climatology Division

The results of this Division's research have far-reaching effects on the Nation and the world. Weather and climate sensitive industries directly or indirectly account for about one-third of the Nation's Gross Domestic Product (GDP). Therefore this Division's research is important to the nation's economy. Furthermore, SMCD applications assist weather prediction modelers and forecasters in the forecasting of aviation hazards, floods, hurricanes, and severe weather. This information plays a role in keeping the population safe.

To manage its projects better SMCD is divided into three branches: the Environmental Monitoring Branch, the Operational Products Development Branch, and the Sensor Physics Branch.

4.1.1 The Environmental Monitoring Branch

The Environmental Monitoring Branch does research in cloud physics, precipitation, aerosols, the radiation budget, and remote sensing of the land. Examples of this Branch's applications include the vegetation and snow cover indices that are used in numerical weather prediction models and products for flash flood guidance that are used by hydrologists.

4.1.2 The Operational Products Development Branch

The Operational Products Development Branch investigates how to obtain useful products from sensors on board satellites that sense meteorological properties like temperature, moisture, and winds. This Branch investigates phenomena that affect the nation's aviation industry, including fog, icing, and turbulence. The Branch studies how best to monitor harmful ultraviolet rays from the sun in order to help inform and protect the public.

4.1.3 The Sensor Physics Branch

The Sensor Physics Branch investigates enhanced sensors that will be used on future missions, the calibration of instruments before and after launch, and better methods of retrieving meteorological parameters from satellite instruments. The only way to use satellites to accurately measure changes in global climate over many decades is to ensure that the instruments on each satellite are calibrated similarly, so the branch strives to improve NOAA's calibration capabilities.

4.2 The Satellite Oceanography and Climatology Division

Satellite Oceanography and Climatology Division

There is little appreciation of the fact that more than 70 percent of the Earth's surface is covered by water, satellites are therefore sensing the surface of the ocean most of the time. The mission of the Satellite Oceanography and Climatology Division (SOCD) is to provide sound scientific research on remote sensing of oceanic properties, such as sea-surface temperature, ocean color, sea-surface wind, sea-surface height, and sea ice.

The ocean plays a fundamental role in determining both weather and climate conditions; consequently, observations of ocean properties directly support weather and climate modeling and forecasting and contribute to the immense social and economic value of forecasting efforts. The United States and the world depend on healthy coasts and oceans; the oceans supply a significant amount of the world's food and resources. Hazards such as harmful algal blooms can lead to significant public health problems, including paralysis and respiratory ailments, with an economic impact averaging $49 million. Commerce is highly dependent on satellite ocean observations, with the United States importing over 9 million barrels of oil daily aboard ships. The Division also responds to the need for stewardship of marine ecosystems, by developing tools such as for monitoring the bleaching of coral reefs, and supporting the protection of endangered species.

The Division is organized into three branches: the Ocean Sensors Branch, the Marine Ecosystems Branch, and the Ocean Physics Branch.

4.2.1 The Ocean Sensors Branch

The Ocean Sensors Branch investigates how to use remote sensing technology to meet the needs of oceanography. The Branch develops techniques to extract ocean properties from data collected by satellites. Using data from visible-light, infrared, and microwave regions of the spectrum, Branch scientists infer the surface temperature of the ocean, and surface winds over the ocean; they also detect the presence of sea ice and oil spills. Other research includes developing optical instruments for use in the water, and microwave measurements on aircraft, to validate satellite measurements of surface wind speed and direction, and other ocean properties. The Branch also defines the physics of the relationships between what a sensor measures and what the end product represents.

4.2.2 The Marine Ecosystems Branch

The Marine Ecosystems Branch analyzes satellite data to extract information on ocean color, sea-surface temperature, surface winds, ice cover, waves, and oil contamination in order to support decisions such as forecasting ocean conditions, monitoring habitats, protecting species, maintaining human health, and promoting sustainable development. The Branch also develops tools for monitoring ocean conditions for an understanding of global climate change, conducting research in a variety of areas from ice-laden polar seas to tropical coral reefs.

4.2.3 The Ocean Physics Branch

The Ocean Physics Branch combines data from radar-based altimeters on board satellites with on-site observations of temperature and winds in the ocean, to determine the ocean circulation and its variability, the marine gravity field, and the topography of the ocean bottom. These are used to map the rise of sea level.

4.3 The Cooperative Research Program

In order to more fully realize the benefits to society of increased exploitation of data from NOAA satellites, STAR has teamed with academic partners across the country at four Cooperative Institutes and one Cooperative Center. Each of the three branches of the STAR Cooperative Research Program (CoRP), consisting of federal government scientists, is collocated with a Cooperative Institute managed by a university. These partnerships enable CoRP to conduct innovative research with current and future professionals in remote sensing. The three federal branches of the Cooperative Research Program are:

STAR's Cooperative Research Program

- The Regional and Mesoscale Meteorology Branch (RAMMB)
- The Advanced Satellite Products Branch (ASPB)
- The Satellite Climate Studies Branch (SCSB)

4.3.1 The Regional and Mesoscale Meteorology Branch

RAMMB is collocated with the Cooperative Institute for Research in the Atmosphere (CIRA) of Colorado State University. This Branch investigates the use of satellite data to improve analysis, forecasts, and warnings for regional and mesoscale meteorological events. Many RAMMB research projects focus on the genesis, development, intensification, and prediction of tropical cyclones and severe thunderstorms. RAMMB is also actively involved in satellite training.

4.3.2 The Advanced Satellite Products Branch

ASPB is collocated with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) of the University of Wisconsin-Madison. This Branch does research in new satellite systems and develops advanced products from environmental satellite data, for monitoring the atmosphere and forecasting the weather.

4.3.3 The Satellite Climate Studies Branch

SCSB is collocated with the Cooperative Institute for Climate Studies (CICS) at the University of Maryland. This Branch investigates the use of Earth observing satellites to study regional and global climate variability. Unique aspects of SCSB include the focus on global climate research, ecosystems methods, and precipitation and hydrological studies.

4.3.4 The Five Cooperative Institutes and Centers

There are five Cooperative Institutes or Centers. Three institutes in Maryland, Wisconsin, and Colorado share a location with CoRP Branches. The institute in Oregon and the center in New York work with CoRP but do not share facilities with the Branches:

- **Cooperative Institute for Climate Studies (CICS), University of Maryland**, College Park, Maryland

- **Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin,** Madison, Wisconsin
- **Cooperative Institute for Oceanographic Satellite Studies (CIOSS), University of Oregon,** Portland, Oregon
- **Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University**, Fort Collins, Colorado
- **Cooperative Remote Sensing Science and Technology Center (CREST), City College of City University of New York**, New York, New York; participating institutions include Bronx Community College (NY), Bowie State University (MD), Columbia University (NY), Hampton University (NY), Lehman College (NY), University of Maryland at Baltimore, and the University of Puerto Rico.

5 Road Map for Science and Technology

The following table and paragraphs map science activities of STAR for the next five years to NOAA Strategic Goals.

Using the NOAA Strategic Plan and the Annual Guidance Memorandum from the NOAA Administrator as guides, STAR develops its own performance goals, measures, activities, and milestones to support the NOAA goals. This document, the STAR Science and Technology Road Map, connects the activities and milestones of STAR to the requirements of the users. For each science project, Research Project Plans (RPP) specifically describe the work to be performed in the next five years, the milestones to be achieved, the financial resources, and the personnel involved.

The NOAA Programs supported by STAR are indicated with an “X” at right. NOAA “Matrix” programs are shaded in blue, and all Programs are organized by Goal.

NOAA Goal	Program	STAR Support
Ecosystems	**Habitat**	X
	Corals	X
	Coastal & Marine Resources	X
	Ecosystem Observations	X
	Ecosystem Research	X
	Aquaculture	
	Enforcement	
	Protected Species	
	Fisheries Management	
Climate	**Climate Observations & Analysis**	X
	Climate Forcing	X
	Regional Decision Support	X
	Climate Predictions & Projections	
	Climate & Ecosystems	
Weather and Water	**Local Forecasts and Warnings**	X
	Coasts, Estuaries, and Oceans	X
	Hydrology	X
	Air Quality	X
	Environmental Modeling	X
	Weather Water Science, Technology, & Infusion Program	X
	Space Weather	
	Tsunami	
Commerce and Transportation	**Aviation Weather**	X
	Marine Weather	X
	Marine Transportation Systems	X
	NOAA Emergency Response	
Critical Support	***Satellite Sub-goal:***	
	Acquisition of Geostationary Satellites	
	Acquisition of Polar Satellites	
	Satellite Services	X
	Fleet Services Sub-goal	
	Leadership Sub-goal	
	Program Support Sub-goal	

STAR's activities and goals that support the NOAA goals and programs are described below.

5.1 Ecosystems

"Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management."

Managing the ecosystems along our Nation's coasts and offshore waters requires detailed observations that will not damage or change the environment being observed. It is possible to monitor these critical resources without causing harm by remotely sensing several properties important to ecosystems from satellites. Concentration of chlorophyll, sea-surface temperatures, sea-level height, and wind velocity can all be estimated directly from satellite measurements. However, this method does have limitations. Clouds and particles in the atmosphere often obscure coastal and oceanic scenes, and the images may not be as detailed as needed because the satellites are hundreds of miles above the water. However, NOAA has successfully observed coastal resources with satellites for many years.

Figure 8. Coral Reef

STAR is able to monitor rapid temperature changes on the sea surface from hour to hour, especially at oceanic fronts caused by currents, eddies, and upwelling of water. Geostationary satellite images provide the data needed to track these rapid and fluctuating changes in water temperature. In addition to directly monitoring the ocean surface from satellite measurements, STAR combines the measurements with field observations and computer model simulations to better understand and predict marine ecosystems. STAR leads the way in this integrated approach to managing ecosystems. Such monitoring contributes directly to three NOAA goals: Ecosystems, Climate, and Weather and Water. STAR also contributes secondarily to the goal of predicting and assessing decadal to centennial change.

5.1.1 Products

Sea-Surface Height

The sea surface height science team—the Laboratory for Satellite Altimetry—provides global, high-quality altimeter data on sea level that helps to explain the rate that sea level is rising, analyze ocean currents, and chart the bottom of the ocean better. These science activities help to meet the three NOAA goals of Climate (variability), Ecosystems, and Safe and Efficient Transportation, respectively.

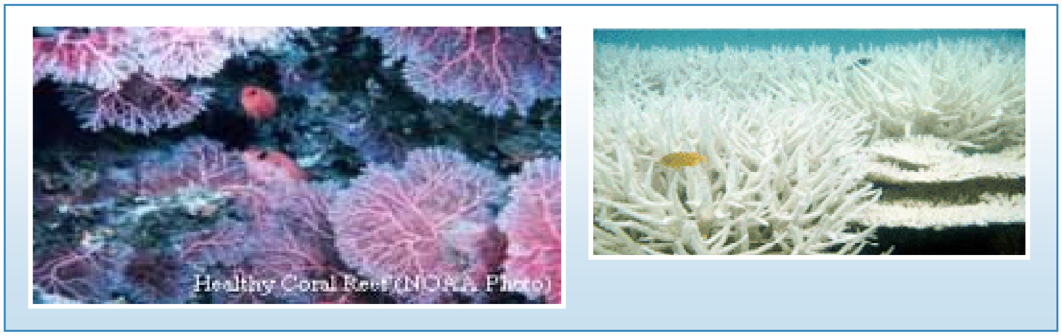


Figure 9. Satellite Monitoring of Coral Bleaching to Improve Survival Rates

Coral Reef Watch and Sea Surface Temperature

STAR delivers sea surface temperature data to both Coast Watch and to the Coral Reef Watch ecosystem projects. A coral reef is a unique, rich ecosystem that supports a vast array of animal and plant species. Coral bleaching is a problem that plagues reefs around the world. Corals bleach or lose the algae living in their tissues when exposed to severe stress, often high ocean temperatures. The elevated water temperatures have been implicated in most of the major bleaching events of the 1980s and 1990s. If the stress is high and sustained, bleached corals will die, damaging the entire ecosystem. NOAA's Coral Reef Watch just released a new satellite warning product for monitoring coral reef health: the Satellite Bleaching Alert system. This tool is an automated e-mail alert system designed to monitor the status of thermal stress conducive to coral bleaching, using the global satellite "HotSpot" suite of products. Figure 10 depicts the departure of sea-surface temperature from normal using a HotSpot product. (Only positive departures are shown). Members of the Coral Reef Watch—a collaboration of STAR and the NESDIS Office of Satellite Data Processing & Distribution—developed the Satellite Bleaching Alert as a tool for coral reef managers and scientists. Alert messages are available for 24 coral reefs around the world at http://coralreefwatch.noaa.gov/.

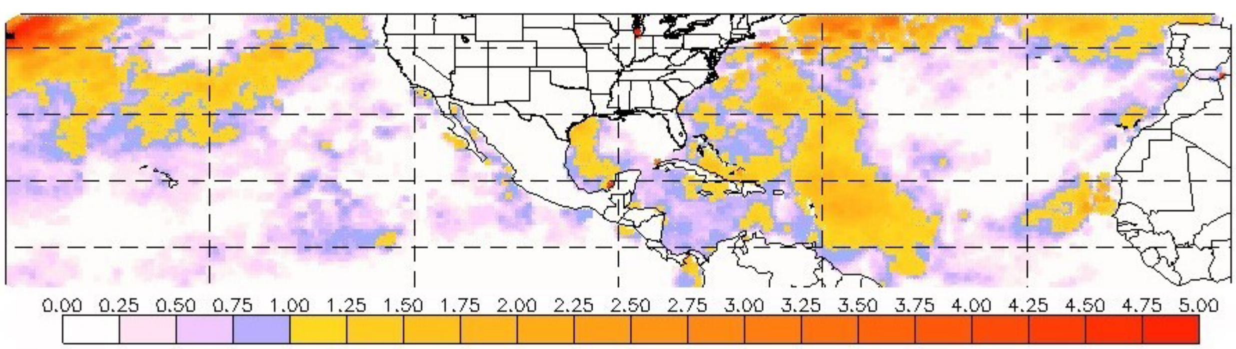


Figure 10. HotSpot Product of Sea-Surface Temperature

Oceanic Phytoplankton

Several projects in STAR document the seasonal and year-to-year variability in phytoplankton in the world's oceans. Phytoplankton are single celled "plants" that form the base of the oceanic food chain. Oceanographers hope to locate the phytoplankton and describe their variation over the short and long term. On a global basis, this can only be accomplished with the use of satellites. The results will serve as a tool to monitor and assess ecosystem health and change. In one project, STAR scientists are using visible satellite imagery to document the distribution pattern of blooms

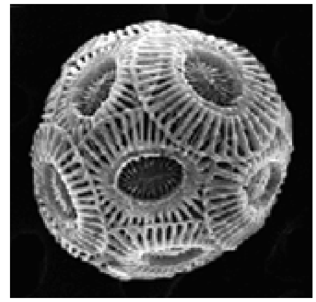


Figure 11. Microscopic view of a coccolithophore

of the phytoplankton called *coccolithophores,* in order to find whether there has been a change in their location and timing over 30 years. Blooms of certain species, such as that shown in the photograph in Figure 11, are detectable in satellite observations, which allow scientists to map their global distribution. High concentrations or blooms of this phytoplankton species profoundly affect the chemical and optical properties of the waters in which they grow. If we can relate the distribution pattern of these blooms to changes in the environment, we may be able to use them as a highly sensitive indicator or *sentinel* species to discern fluctuations associated with climate variability or change. For this purpose, the changes in distribution of this phytoplankton species over time should be mapped from space, as in Figure 12.

Predicting Marine Organisms

STAR scientists use satellite, model, and *in-situ* data to predict marine organisms that are important to society. Our goal is to develop the ability to detect, monitor, and predict the location of these marine organisms important to society in coastal and global waters. To this end, STAR is part of a project to predict the location of sea nettles (a stinging jellyfish) and harmful algae (one-celled plants) in the Chesapeake Bay, as well as to develop and implement an ecological model of the Chesapeake Bay watershed and estuary.

Locating Sea Nettles

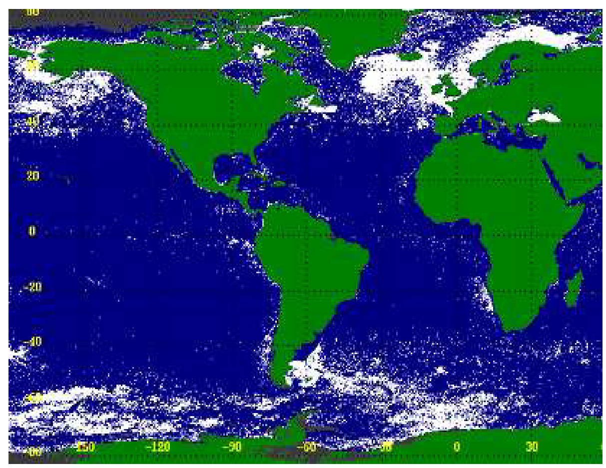
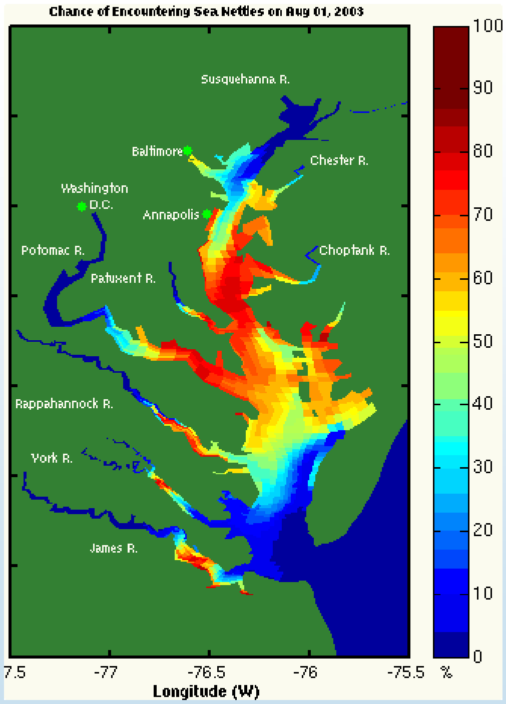


Figure 12. Abundance (in white) of the phytoplankton species *Emiliania huxleyi* in SeaWIFS satellite imagery.

Sea nettles (Figure 13, right) seasonally infest the Chesapeake Bay, affecting commerce and recreational activities. Maps (Figure 13, left) are created from satellite measurements and computer models. These *"nowcasts"* are updated daily to indicate where environmental conditions are favorable to the presence of sea nettles. Recreational boaters and swimmers use these maps to locate areas of water free of sea nettles and their stinging tentacles. Sea nettles also prey on the early life stages of fish and fish prey, and it is important to know how variations in their population might affect the food web and the fisheries of Chesapeake Bay. STAR uses computer models and satellite data to identify areas of moderate salinity and warm water—conditions that sea nettles prefer—to predict where the nettles are likely to occur. STAR plays a vital role by hosting the demonstration web site of the nettle nowcasts through its CoastWatch Program. STAR scientists will enhance this system's capabilities by incorporating other satellite-derived products into the nowcast procedure. For a recent map of sea nettle distribution in the Chesapeake Bay, see http://coastwatch.noaa.gov/seanettles. This demonstration project is ready to be transferred to operations.



"As a sailboat owner who really NEEDS to swim when the temps are above 90F (and the cabin is over 100) - I was delighted to find your probability map and put it to use this weekend. After turning tail from the bottom of the Choptank on June 29 (always a nettle wherever you looked) - we checked your map and trailered the sailboat to Claiborne, MD on July 2. The Bay was nettle-free all the way to the Western Shore and back. … Thanks for your work on the map."

Vaughn Volungis, Denton, MD

Figure 13. Sea Nettles— Predicting a Biotic Nuisance

Harmful Algal Blooms

Harmful algal blooms (HABs) adversely affect human health and the health of marine organisms. The annual economic impact of algal blooms averages $49 million in the United States. With sufficient warning, coastal resource managers and local authorities have more time to mitigate the harmful effects of HABs. STAR develops products that help monitor the blooms. Like the sea nettles project, this project locates regions where environmental conditions are favorable for the development of these blooms. STAR will implement an operational system that will forecast the likelihood of blooms of several harmful algal species in Chesapeake Bay over the next five years. For more information, visit the Coast Watch site (cosponsored by STAR) at NOAA Coast Watch Collaborative Projects.

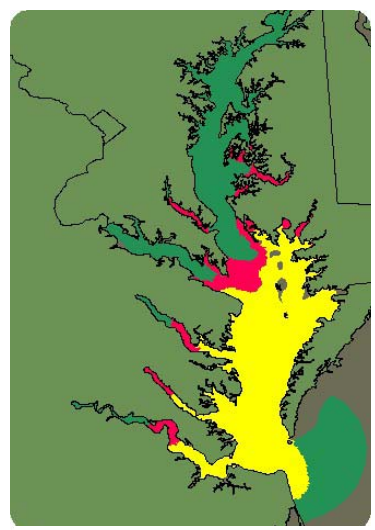


Figure 14. Relative abundance of an algal species harmful to fish, in Chesapeake Bay, April 2005.

STAR also assists the NOAA's National Ocean Service in locating HABs in the Gulf of Mexico and informing users about the blooms. To do that, STAR provides satellite-derived estimates of chlorophyll concentration and other ocean-color products for use in their Forecasting System.

STAR and its partner organizations at the University of Maryland are implementing an ecological model of the Chesapeake Bay watershed. This forecast system consists of coupled atmospheric, land, and ocean models complete with biological and geochemical components. The ecological model will employ on-site direct observations and satellite-derived measurements to enable applications in real time, and support investigations of climate change. The approach dovetails into NOAA's ecosystem and climate goals as well, since we must understand processes presently operating in the ecosystem, if we are to forecast the response to climate change in the future.

Ocean Color

The Ocean Color Science Team works to derive the greatest benefit from current satellite observations of visible light in the oceans. In order to reduce uncertainties in our measurements of color and brightness of light from the oceans, the team calibrates the satellite data with measurements taken in the water by the Marine Optical Buoy (MOBY), an unmanned scientific observatory in the Pacific Ocean off Hawaii.

STAR investigates how to use high-quality data on ocean color for the benefit of marine scientists, coastal resource managers, public health officials, and the public. The data are used for maintaining marine ecosystems, for supporting sustainable fisheries, and for monitoring climate trends and variability. Ocean color products directly support the NOAA goals of understanding climate change and variability, and stewardship of ecosystems in the oceans.

The MOBY project has now provided over nine years of nearly continuous calibration data that has been critical in meeting specifications for the satellite data and in creating climate date records for ocean color. The team validates measurements of ocean color by measuring properties of the ocean with instruments on the Buoy at the same time that the satellites measure these properties. The Team is also exploring new products and applications; these include indices of water quality such as turbidity, and physiological parameters such as primary productivity.

In the next two decades, sensors of ocean color are planned on both the new polar-orbiters and the geostationary satellites. The Team is preparing for the upcoming polar-orbiting sensor, the Visible-Infrared Imager/Radiometer Suite (VIIRS) to be launched in 2009 on the NPP satellite. They are anticipate even better sensing capabilities on geostationary platforms: the Advanced Baseline Imager (ABI) and Hyperspectral Environmental Suite (HES) instruments on board the next-generation GOES-R satellites will expand NOAA's capabilities to monitor and derive oceanic, terrestrial, and ecosystem properties, and to assess ecosystem health. The capabilities of the HES-CW (Coastal Waters) instrument to image coastal waters will revolutionize our ability to assess, monitor and predict U. S. coastal regions.

An emphasis in future ocean color satellite sensors will be coastal water applications which present new challenges in developing products. Color data is well described and understood in the open ocean, but sensing of coastal environments presents difficulties in atmospheric corrections and the need for higher resolutions. The Ocean Color science team is overcoming these difficulties by improving atmospheric correction techniques and developing new regional algorithms for ocean color products.

NOAA CoastWatch Becomes Global OceanWatch

Over the next several years, the NOAA CoastWatch Program will be incorporated into the OceanWatch Program. NOAA will transfer its capability of observing and monitoring the U.S. Coasts to a capability for monitoring all ocean waters on the planet. The program will look at the impact of data from the future polar-orbiting series of satellites, the National Polar-orbiting Operational Environmental Satellite System (NPOESS). Under OceanWatch, STAR scientists will support the satellite requirements of the "Integrated Ocean Observing System."

Activities	NOAA Performance Objective	Outcome
• Develop products that enhance our ability to monitor the ocean's ecosystems • Combine remotely sensed ocean observations into a suite of products.	• Increase number of regional ecosystems in coastal and marine areas having approved indicators of ecological health and offering benefits to society that are understood and monitored	• Healthy, productive coastal and marine ecosystems that benefit society • A well-informed public that acts as a steward of coastal and marine ecosystems

5.2 Climate

"Understand climate variability and change, to enhance the ability of society to plan and respond."

Using satellite data intelligently, scientists can successfully monitor many aspects of climate change and variability.

5.2.1 Products

Sea-Surface Height and Sea Level

The sea-surface height team uses high quality "altimeter" data from satellites to support the NOAA climate goal by

1. Determining the rate that sea level is rising globally,
2. Forecasting El Niño events, and
3. Monitoring ocean currents.

It is extremely important in climate science to monitor sea level, including the rate at which it is rising. Both the rate and causes of sea-level rise are the subjects of intense controversy. Satellite altimeter observations since 1993 show that sea level has been rising steadily at 28 mm/decade, whereas tide gauges over the past 100 years show a slower trend of 18 mm/decade. It is not clear whether this demonstrates a long-term increase with respect to the historical rate or it results from decade-to-decade variability. The Sea-Level Rise project attempts to determine the rate of sea-level rise and its causes, using all data associated with satellite altimeters.

The STAR science team has the responsibility for producing and archiving the research quality data set for the Geosat Follow-On satellite altimeter mission of the U.S. Navy. This mission will continue to provide the operational measurement of sea-surface height until 2006. The next major goal will be to oversee the operational flow of data from the new Jason-2 satellite, beginning in 2008. For the first time, NOAA will bear the responsibility for the instrument and operational data, along with its Navy and European space agency partners.

Ocean Currents and El Niño

STAR monitors currents at the ocean surface with satellite data. The program—called OSCAR (Ocean Surface Current Analysis Real-time)—monitors basin-scale surface currents in the tropical Pacific Ocean and the changes associated with El Niño. OSCAR analysis is based on three sets of data, all from satellites: height from altimeters, surface winds from microwave scatterometers, and sea-surface temperature (SST). The OSCAR analysis, which is entirely automated, calculates the velocity of ocean surface currents. Ten years of data are now available for interactive display and downloading.

Maps of ocean currents permit early detection of changes in the El Niño cycle. OSCAR shows clear evidence of shifts in the water circulation well in advance of changes in the surface temperatures. OSCAR was transferred to NOAA/NESDIS for routine operation in 2004. A follow-up NOAA mission, OSCAR-II, will extend the analysis of currents to the tropical Atlantic and Indian Oceans and eventually to middle and high latitudes in all oceans.

Ocean Color

STAR oceanographers develop and validate algorithms for ocean color for oceanic bio-optical products. This provides set of long-term, consistent, and calibrated data and products that are valid across multiple missions and satellite sensors. The overall goal is to measure climatically significant bio-optical products with enough accuracy to distinguish sampling and measurement biases from responses to climatic forcing. Biological responses to climate change are subtle and smaller than temporary intra-annual variations and mesoscale spatial variations. The current capability for measuring phytoplankton biomass *in situ* and from satellites is insufficient to distinguish community responses to climate change from natural variability. For a wider range of ocean color products, see Section 5.1.

Global Precipitation

STAR participates in the World Climate Research Program's (WCRP) Global Precipitation Climatology Project (GPCP) by developing algorithms for, and delivering maps of, monthly rainfall around the globe, as observed in polar-orbiting satellite data. A team is responsible for assessing the quality of precipitation data sets and other hydrological products, such as snow cover and precipitable water, going into GPCP. This time series is nearly 20 years in length and the GPCP will continue through at least 2010. Most importantly, these products may be useful for investigating the global water cycle - the focus of the next phase of GPCP over the next five years. Additionally, STAR will develop new schemes for merging data from all available microwave sensors on the polar-orbiting satellites to improve their accuracy substantially, and to generate climate data records (CDR) of precipitation, to be used by NOAA scientists to investigate global precipitation trends.

Monitoring Greenhouse Gases from Space

The amount of carbon released into the atmosphere by industrial sources is reasonably well known, as is the steadily increasing mean concentration of atmospheric carbon dioxide (CO_2). What is not well known is the rest of the carbon cycle—the magnitudes of the natural sources and sinks of CO_2 at the Earth's surface. Poor knowledge of the sources and sinks of carbon impedes the understanding of global climate change.

Using NASA's Atmospheric Infrared Sounder (AIRS) instrument, scientists in the Satellite Meteorology and Climatology Division can now determine the concentrations of three important trace gases in the atmosphere: CO_2, methane (CH_4), and carbon monoxide (CO). The first two are significant greenhouse gases, and all have significant effects on climate.

With collaborators at the University of Maryland, Division investigators have shown that CO is a robust and useful product from the AIRS sounder. CO is important because it is a component of air pollution, is a measure of biomass burning, and contributes to the greenhouse effect. STAR has also developed techniques for measuring CO_2 and methane from AIRS in orbit. The team has developed a suite of greenhouse gas products from the AIRS instrument and is producing daily experimental global greenhouse gas maps. Such maps will enable researchers to define the Earth's carbon cycle more clearly.

Ozone

STAR develops a reliable product for monitoring ozone (Section 4.2.1) for the National Weather Service, which issues a forecast of ultraviolet radiation. Climate scientists also use this product to investigate how ozone and other heat-trapping gases affect the climate.

Sea Ice

STAR also has a Sea Ice science team that will develop the techniques and the products for monitoring sea ice. Such knowledge about where the ice is located will be essential for forecasting regional climate on 30- to 90-day time periods. For more details, see Section 5.4.1.

Fires and Aerosols

Fires are a large source of aerosols, which have a strong effect on climate. Thus, the Aerosol Project offers a high-quality product from NOAA satellites for investigating the impact of aerosols on climate change. For examples of the Aerosol and Fire products, see Section 5.3.2.

5.2.2 Long-Term Data Records

Reprocessing Satellite Data for Climate Studies

STAR has begun to reprocess the entire global record of data from the Advanced Very High Resolution (AVHRR) instrument onboard the operational NOAA satellites. Having obtained the full set of AVHRR images from 1980 to 2005, this project is applying a lesson learned over the last 25 years— the quality of the image data and products must be improved when reprocessing them for climate studies. For example, the team had to improve the calibration and location accuracy of the historical imager data. Over the next five years scientists will produce new and more detailed climatological data sets for the global vegetation index over land, sea-surface temperatures and aerosols over oceans, winds in polar regions, and clouds. Some results on the variability of high cloud amount over the 15-year period are shown in Figure 15. In the coming years, STAR will reprocess data from other satellite instruments with more advanced data sets, in order to improve the long-term records of climatic data. These data will span almost 30 years, and will help us to gain a better understanding of climate variability and change.

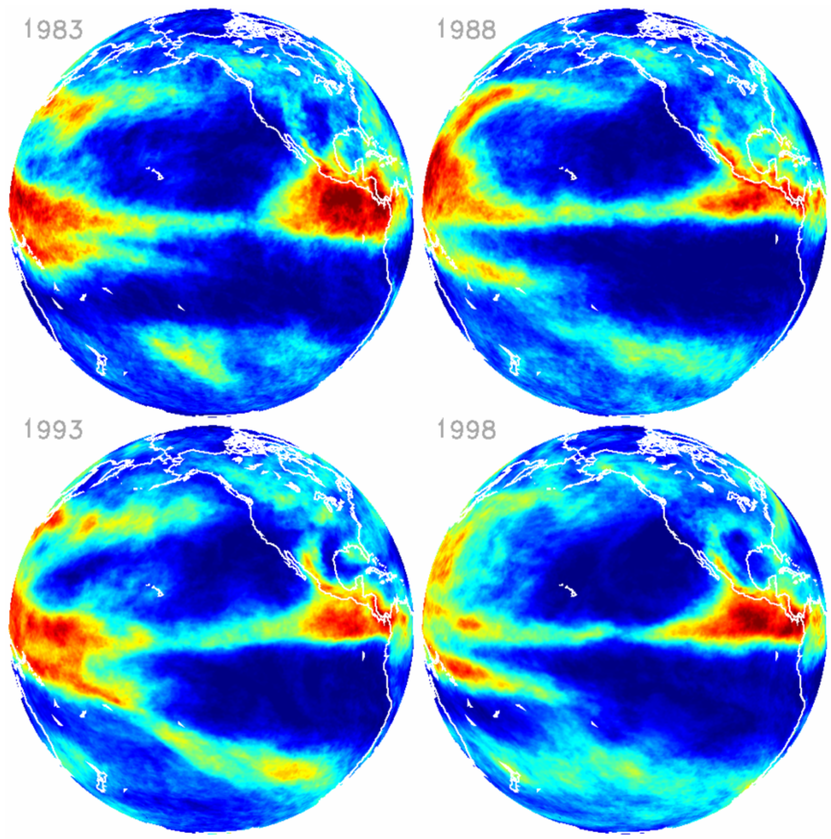


Figure 15. Example of a new climate data set from reprocessing polar orbiting images. The globes show the year-to-year variability in high clouds from data in July for four different years, 1983, 1988, 1993 and 1998. Areas with large amounts of high cloud are red, while areas with less high cloud are blue.

Sea Surface Temperatures

STAR is generating high-quality data sets of sea-surface temperatures (SST) over the next several years to enable climate scientists to investigate the effect of the sea's temperature on global climate. In order to be useful in long-term climate studies, data must meet rigorous standards for accuracy, precision, coverage of the Earth, sampling, and resolution. The best data sets, called **Climate Data Records** (CDRs), will be built by STAR scientists.

They will investigate the effect that higher resolution will have on these records (future satellite instruments are designed to have much higher resolution). They will blend different types of satellite data to improve the quality and broaden the utility of sea-surface temperature products.

STAR is generating Climate Data Records of sea-surface temperature from the Polar Orbiting Environmental Satellites (POES) from 1981 to the present and from the Geostationary Operational Environmental Satellites (GOES) from 1994 onward. During that process, the higher spatial resolution and better spectral coverage from the AVHRR on POES improve the screening of clouds and increase the accuracy of the temperature record, while frequent imagery from GOES is used to resolve the daily cycle of temperature. Blending the SST data from POES and

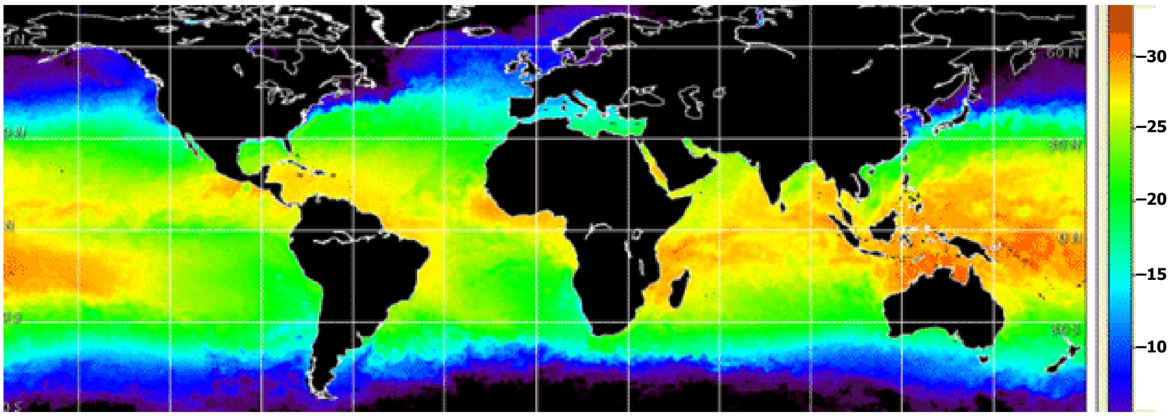


Figure 16. New STAR Sea-Surface Temperature daily product blending polar (POES) and geostationary (GOES) satellite temperature observations for the entire globe.

GOES (Figure 16) improves the quality and utility of the product. STAR evaluates the satellite-based temperatures against ground-based SST data from buoys and ships, various climatologies, and *re-analysis* products of the NWS and European centers.

Future work will include a “stewardship system” that allows multiple recalculations of the data to obtain progressively more accurate SST. Climate-quality SST requires better cloud screening and better calibration of the sensors. To correct sea surface temperature data for the presence of aerosols in the atmosphere above, systems that retrieve the aerosol amount (a product that is much desired) as well as the SST are starting to be used. Finally, better ground truth from buoys and ships are needed to evaluate the Climate Data Records of SST.

The atmospheric sounding instrument (AIRS) on NASA’s satellites produces enormous volumes of data—approximately 35 GB/day of raw data. STAR provides the climate community with global gridded products at full spectral resolution, so the community can evaluate whether existing algorithms are good enough or whether data need reprocessing. Finally, the STAR team is combining imaging data with sounding data to improve all of the atmospheric products.

Activity	NOAA Performance Objective	Outcome
• Build archives of satellite data products over extended periods of time to be used in climate research	• Reduce the uncertainty in climate projections through timely information on the forcing and feedbacks that cause changes in the Earth's climate • Describe and understand the state of the climate system through a smart combination of observations, analysis, and stewardship of data	• A much better understanding of the global climate system, enabling society to predict climate for periods ranging from weeks to years to decades; uncertainties will be specified sufficiently well so that leaders can make informed decisions • Climate-sensitive sectors of society and the climate-literate public incorporate NOAA's climate products into their plans and decisions

5.3 Weather and Water

"Serve society's needs for weather and water information."

Natural catastrophes—such as floods, severe storms, and hurricanes—cause 7½ times more insured losses across the globe than manmade disasters. The work of STAR to develop the tools needed to observe and understand such catastrophes and their precursors helps those who predict these catastrophes, as well as those who must plan for or manage natural disasters.

5.3.1 Assimilation of Data into Models

Environmental data from satellites is vital for setting initial conditions for the operational numerical models of weather prediction. Satellite sounding data make up most of the volume of information going into forecast models of the National Weather Service. STAR's research strives to provide more accurate surface boundary conditions for operational prediction models.

In the next five years, STAR scientists will create new and improved products (in boldface below) from satellite measurements, for input into numerical weather prediction models. The goal is to continue to improve the accuracy of forecast models and weather forecasts.

STAR is deriving a product for **radiative flux at the Earth's surface** from GOES satellite observations and other measurements of solar radiation (insolation). These new products, in addition to **indices of vegetation** derived from satellite data (Figure 17), will be used in land surface models of the National Weather Service (NWS). Scientists are also investigating **cloud properties** for use as a possible product that NESDIS can deliver to the Weather Service.

For **sea surface temperature** (SST), the most recent trend is to assimilate radiance measurements rather than the temperatures derived from them. Both approaches require accurate and cloud-free measurements. STAR scientists will improve the cloud mask product as well as the calibration of the sensor, thus improving the radiance measurements. SST data are needed for many outside users, and provide a valuable check of the quality control of cloud-free, calibrated measurements of radiance.

Algorithms that estimate **precipitation** will be improved and tested for accuracy in atmospheric and hydrologic prediction models in regions where precipitation observations are not available from other sources. The Ozone Project produces high-quality **ozone estimates** for use in weather prediction models. STAR scientists work with atmospheric modelers to diagnose and predict emissions of **aerosols** and **trace gases** from fires and their subsequent transport. Results are used in **fire products** that will be tested in weather prediction models.

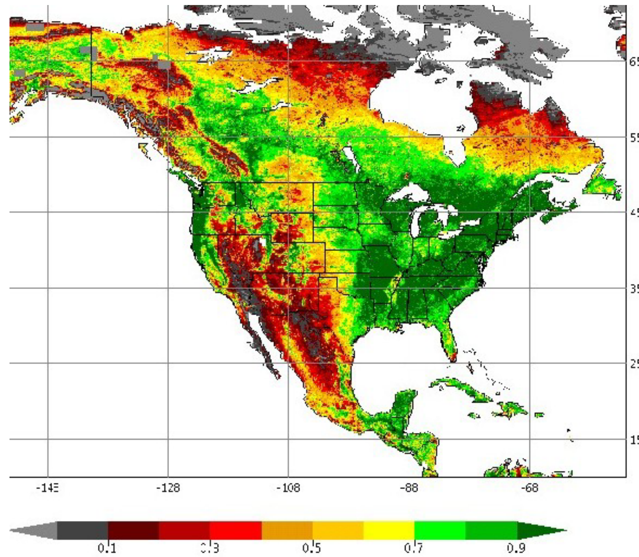


Figure 17. A Green Vegetation Fraction product in June 2005

STAR research has yielded better estimates of **ocean surface winds** around low pressure centers in high latitudes; these estimate help predict the strength and motion of snow storms, severe weather, and hurricanes**.** STAR developed procedures for estimating wind speed and direction at various heights from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's *Terra* and *Aqua* satellites. STAR generates the wind vectors experimentally in real-time for the European Centre for Medium-Range Forecasts (ECMWF), for the National Center for Environmental Prediction (NCEP), for NASA, and for six other national weather prediction centers. The future direction of this research is to produce detailed maps of ocean surface winds in coastal waters and in the open ocean, from satellite-borne radar. These maps have proven to be invaluable in forecasting many types of coastal phenomena, including barrier jets and katabatic winds.

For all of these products, STAR scientists study the effect that data with better spatial resolution and coverage will have on prediction models and forecast accuracy. In general, new instruments to be put on NOAA's future satellites will transmit data of better resolution. Observations and data from future GOES satellites will also be more frequent than they are now.

STAR is investigating techniques that take advantage of the more frequent imagery when used in weather prediction models. One way is to generate short-term (three to six hour long) forecasts of product imagery.

STAR is developing the **Community Radiative Transfer Model (CRTM)**, which will be used in numerical weather prediction models. This model will accelerate the use of future satellite data in weather and climate predictions and may lead to improved predictions of clouds and precipitation, which are currently difficult to predict. Radiative transfer is the glue that connects satellite observations to atmospheric properties being observed. The goal is to reduce the time it takes to transfer new satellite technology into operations from two years to one year.

AIRS produces a huge quantity of radiance data every day. The weather forecast models of the NWS cannot ingest such a large volume of raw data, so STAR extracts a product from the raw AIRS data that is ten times more compact, without measurably losing the information content. STAR will make further improvements in this process for future sounders (see Section 5.5.5).

STAR is improving a system that delivers polar-orbiter (POES) and GOES **sounder products** to the NWS at maximum resolution (approximately 10 km) for use in weather prediction models and its data display system. Specifically, these products will include: clear-sky radiances, water vapor content both in layers and in the entire depth of the atmosphere, indices of atmospheric stability, satellite cloud products (such as cloud-top pressure, cloud-top temperature, and effective cloud amount) and imagery depicting all of the above. There will also be a product for total ozone amount. These sounder products will continue to be the foundation of information from the GOES sounder over the next five years.

5.3.2 Real-Time Satellite Products

Most of the Center's research involves developing satellite products that support NOAA's Weather and Water goal, in order to help the National Weather Service monitor current conditions in the atmosphere, to enable forecasters to predict the weather, and to warn of weather hazards. Once the real-time observations are quality-controlled and verified against ground truth, they become Environmental Data Records STAR tests the use of data from many instruments on both NOAA and non-NOAA satellites. STAR scientists also study the effect that data from future satellites may have on short-term forecasting.

Sea-Surface Temperature

Sea-surface temperature (SST) products contribute to forecasters' ability to assess the state of the ocean surface and to improve the accuracy of weather forecasts. STAR scientists are testing the effect that more detailed data available in the future will have on SST maps and forecast accuracy. The Center's sea-surface temperature products also support the Climate goal (see Section 5.1.1).

Rainfall Estimates

Observations of rain are important for a wide variety of applications, from the prediction of flash floods to the evaluation of the long-term water supply. Since radar and rain gauges are available for only a small portion of the Earth's surface (mostly over land), for more than 30 years, STAR has supported weather forecasters and water-management agencies with precipitation products from satellite data. The rainfall estimates cover wide areas of the Earth's surface, but their accuracy needs to improve. There are now several opportunities for a more accurate product, including the launch of new satellites with new sensors and the optimal blending of data from different instruments to take advantage of the strengths—and avoid the limitations—of each. In 2005, this team began to merge the data from polar satellites and geostationary satellites in order to get the best possible estimates of rainfall around the globe. The goal is to create a single algorithm that captures the strengths of the existing techniques of rainfall estimation.

In upcoming years, STAR scientists will improve the physically based algorithms for deriving rainfall and port them to the wide array of new sensors to be put into operation over the next ten years. These sensors will ensure continuity from current POES satellites into the era of the future NPOESS missions. The team is also testing techniques that extrapolate the current distribution of rainfall a few hours into the future.

Wind Measurements

In the last few years, the ability to observe the speed and direction of surface winds just above the oceans has improved dramatically thanks to better satellite data and techniques. The wind products available from current and future satellites are better than ever. Remotely sensed wind speed and direction data are vitally important to improving forecasts of storms on the coasts and in the open ocean. There are two challenges: to fully utilize the present sensors and to make tradeoffs between active and passive sensing techniques on future NOAA satellites.

STAR participates in several wind projects: tracking cloud features in *GOES* and *MODIS* images, the *Windsat* mission, and the *QuikSCAT* mission. The MODIS Winds project was mentioned in Section 5.1. STAR recently transferred this capability to its operational partners within NESDIS. To make the MODIS winds available to weather prediction models in a more timely fashion, STAR will experiment with producing MODIS winds at sites in the Arctic and Antarctic.

Windsat, a microwave instrument designed and built by the Navy, will serve as the first demonstration in space of a passive technique for observing surface winds over the ocean. That technique will be standard on the next generation polar-orbiting satellite system (NPOESS).

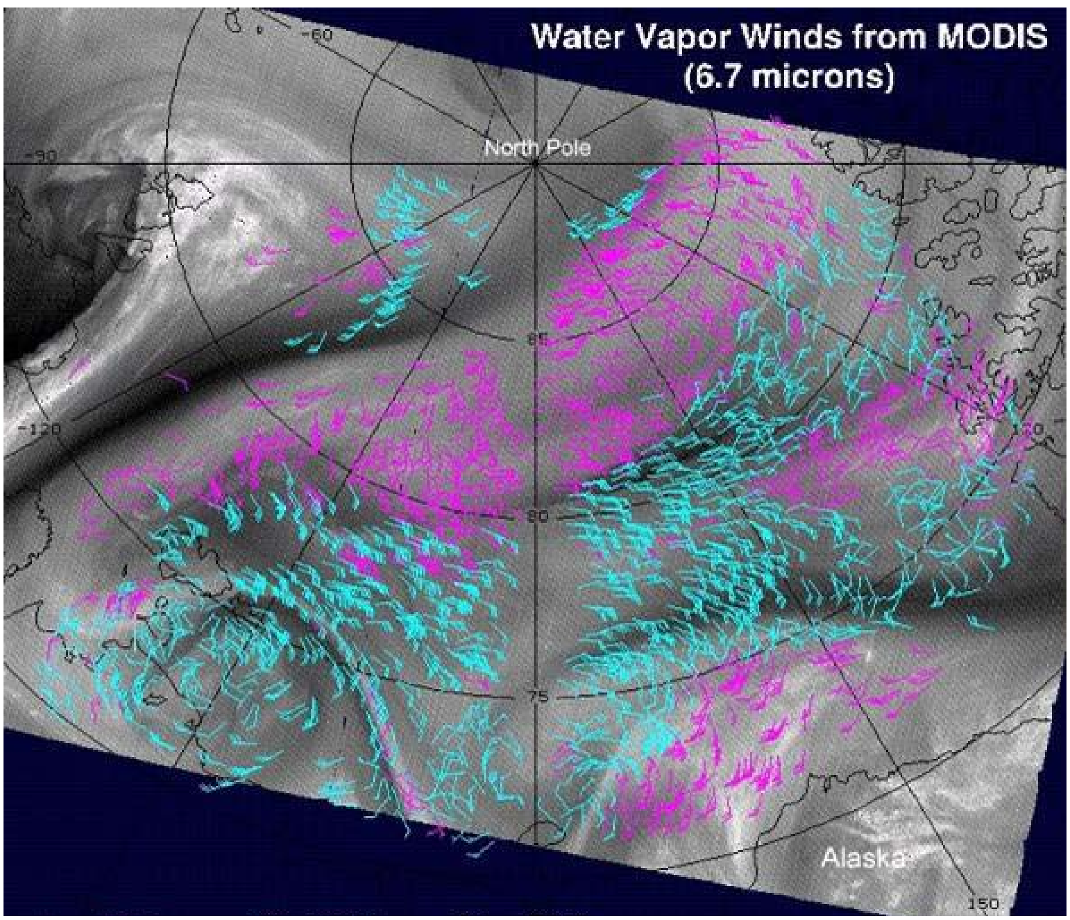


Figure 18. Winds derived from motion of features on MODIS images

STAR supports the sensing system for *QuikSCAT* wind products, used operationally by NWS, and will also support it on the next series of European satellites, even though many different sensors and processing techniques will be used.

For both geostationary and polar-orbiting satellites, STAR scientists define requirements for wind measurements, develop products, verify and improve the products, and reach out to users. STAR investigates problems that degrade the quality of operational wind products and finds solutions to correct them. To facilitate such improvements, STAR set a major objective of establishing a robust process for successfully transferring new wind products from a research setting into operations.

Tropical Cyclones and Hurricanes

STAR is improving the monitoring and forecasting of tropical cyclones. The most pressing need is to estimate the current intensity, location, and size of hurricanes and, once they form, to predict subsequent changes in intensity.

Hurricane Katrina intensified rapidly from Category 1 to Category 5 one day before it reached New Orleans in August 2005. Press reports suggest that warm ocean waters intensified Katrina, but sea- surface temperatures were uniformly around 30°C almost everywhere along Katrina's path. If sea surface temperature alone causes intensification, Katrina would have strengthened gradually. Instead, Katrina intensified most rapidly when she was over areas of dynamic high sea level height (or topography) measured by satellite altimeters (see Figure 19). These centers are collocated with regions of high heat content in subsurface waters. It is the depth of warm water—not just the temperature at the surface—that provides the reservoir of energy to intensify a storm.

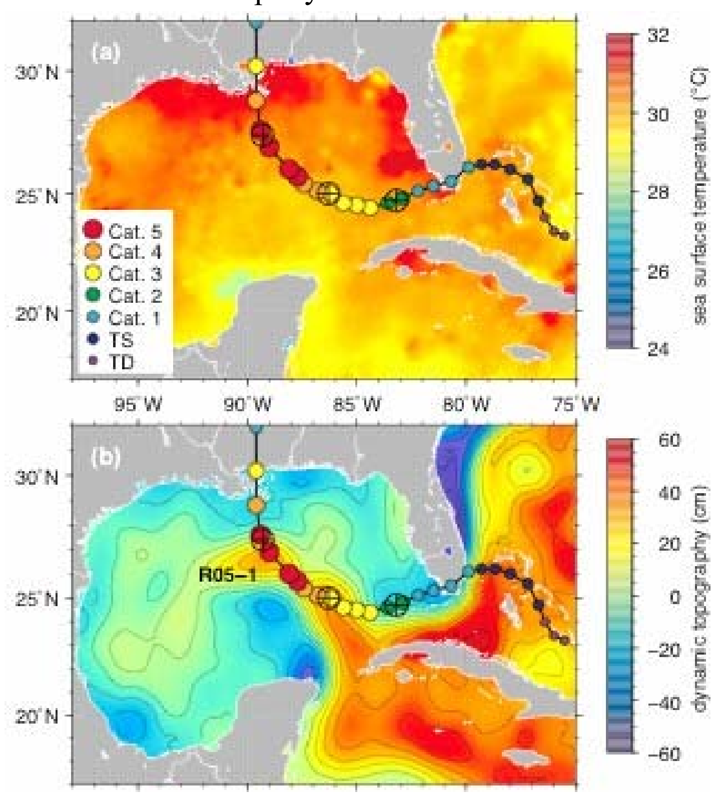


Figure 19. Hurricane Katrina intensified from Category 2 to 5 when it crossed regions of high oceanic heat content, which are regions of high topography detectable by satellite altimetry (lower map). Coincident sea surface temperature data (top map) does **not** clearly suggest hurricane intensification.

NOAA routinely uses satellite altimeter measurements of sea-surface height to estimate tropical cyclone heat potential and its impact on hurricane intensity. The lower image indicates that Katrina intensified to Category 5 as it passed over a narrow region of high heat content in the Gulf of Mexico. In contrast, plots of sea surface temperature in the upper image show uniformly warm temperatures along Katrina's path.

In the 1990s, STAR worked with the NOAA Hurricane Research Division to develop a statistical model—the Statistical Hurricane Intensity Prediction

Scheme (SHIPS)—to predict the intensity of hurricanes. However, the SHIPS model does not consider variables such as the convective activity near the storm center or the sub-surface ocean temperature. Since these factors are important, STAR recently began to use satellite imagery in the SHIPS model to provide a measure of the convective activity and its location. STAR is also using SHIPS to incorporate the satellite altimetry data mentioned above to estimate the true oceanic heat content and its influence on intensifying hurricanes. STAR partnered with the National Hurricane Center and the University of Miami to transfer these new hurricane forecasting products to the operational forecasting desk at the National Hurricane Center.

STAR can provide another valuable future product using satellite altimetry data. When Hurricane Katrina approached the Gulf Coast in August 2005, three different altimeters observed a broad bulge of higher-than-normal sea level to the right and downwind of the eye. This was apparently the first observation of the wind-driven storm surge that inundated the Gulf region.

The probability of encountering hurricane force winds is the subject of another product developed by STAR, in a NESDIS project funded by the Joint Hurricane Test Bed. A new model estimates the likelihood of winds exceeding 34, 50, and 64 knots at any location in forecasts from 0 to 5 days. Figure 20 shows the probability of hurricane force winds occurring at any time in a five-day period, when Hurricane Rita approached Texas. NESDIS provided the program code to the National Hurricane Center, which used it for all storms in the 2005 season.

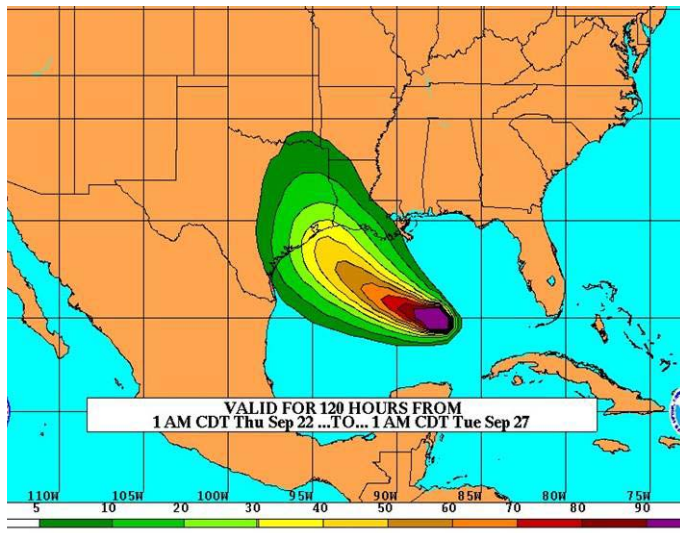


Figure 20. Probability (%) of winds exceeding hurricane force in a five-day period, in September 2005 for Hurricane Rita

Ozone

NESDIS launched an Ozone Project that generates short- and long-term monitoring products from instruments on the NOAA satellites. STAR works on several fronts: with NESDIS operations to improve operational products; with the Climate Change Science Program, NASA, and the National Climatic Data Center (NCDC) to create long-time series by reprocessing many years of data on ozone; and with NASA to improve the algorithms and calibration. The goal of STAR is to produce high quality estimates of ozone amount for weather forecast models, forecasts of ultraviolet (UV) radiation exposure, and scientific studies.

In recent decades, various human activities have released ozone-destroying chemicals into the atmosphere. Starting in 1980, a massive, continent-sized hole appeared over Antarctica and has grown during subsequent years. Working with NOAA's Climate Prediction Center, NESDIS continues to closely monitor the Antarctic ozone hole. Extensive ozone depletion was again observed over Antarctica during the southern hemisphere spring of mid-2004, with widespread anomalies of 45 percent below the base period of 1979-1986. The area covered by extremely low total ozone values, defined as the *ozone hole*, reached a size of greater than 19 million square kilometers in 2004 (which is smaller than earlier years).

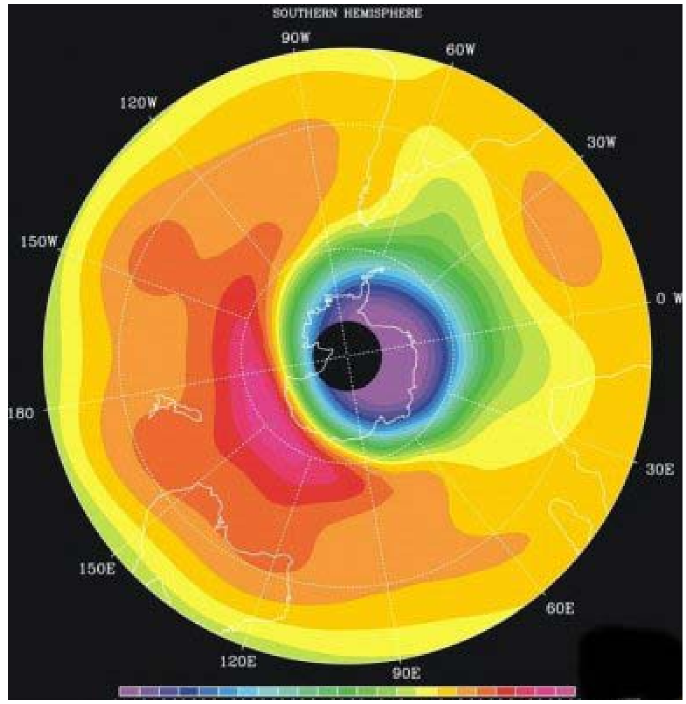


Figure 21. Ozone concentration in southern hemisphere stratosphere, SBUV-2 sensor, NOAA satellite, Oct 2001.

Figure 21 shows the average ozone estimates at the 30 mb level in the stratosphere for the southern hemisphere in October 2001. The estimate is based on measurements taken from a NOAA polar-orbiting satellite. The very low concentrations (indicated by the purple region) are evidence of severe ozone depletion. The satellite-observed ozone data will measure the recovery of the ozone layer from the losses sustained by decades of pollution.

Ultraviolet Radiation

STAR scientists will develop a reliable product for surface ultraviolet (UV) radiation derived from geostationary (GOES) satellite data that will be a reference for evaluating the National Weather Service's Ultraviolet (UV) Index forecast. They will use GOES visible light data and existing ozone and water vapor information to estimate the UV radiation at the surface. Instead of using a parameterization, as is done now, STAR will calculate the radiative transfer of ultraviolet radiation. This new product will include all of the flavors of ultraviolet radiation: type A, type B, and erythermal radiation. The new GOES product will be superior to similar products using polar satellite (POES) data because for most biological processes, the relevant quantity is the daily dose integrated over a day. The daily dose can be determined more accurately from geostationary satellites.

Vegetation Health

The two most important applications of vegetation products from satellites are to assess short-term drought and its impact on agriculture and hydrology, and to specify boundary conditions in numerical weather prediction models. At present the operational products are a vegetation index, a fraction of green vegetation, and a variety of indices of drought and vegetation health. The "Green Vegetative Fraction" (GVF) product shows how much of the land surface is covered with actively growing vegetation (Figure 17 for North America, and Figure

22). Another product indicates whether the health, vigor, and amount of vegetation in a particular area are above or below normal for the time of year. Together with satellite observations of land surface temperatures, these STAR products are used to monitor drought conditions globally.

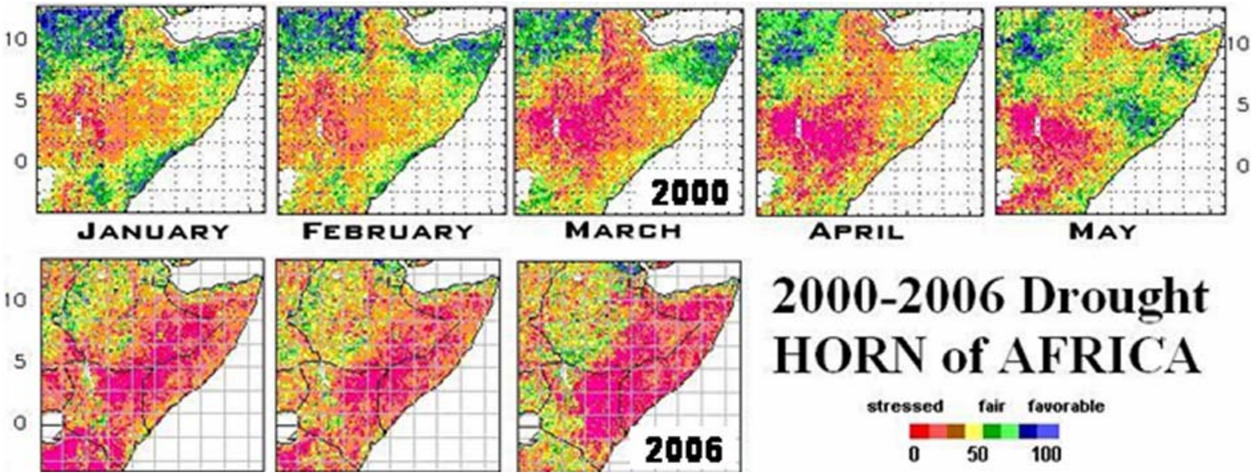


Figure 22. Drought in the Horn of Africa in 2000 and 2006.

Since 2000, drought conditions have affected nearly 20 percent of the world. For the past six years, NOAA polar-orbiting satellites have mapped crippling drought conditions in parts of the world, including the Horn of Africa (red color on Figure 22). AVHRR, an imaging instrument on NOAA's polar satellites, measures the amount of solar reflection from green vegetation, which directly correlates to the content of chlorophyll in plants. STAR researchers develop indices that estimate vegetative moisture, ambient thermal conditions, and the overall health of vegetation. The methodology and products developed by STAR for monitoring vegetative conditions are routinely used to warn the global community about the dangers of long-term drought.

Imaging instruments on NOAA's future satellites will have better resolution and different spectral bands than the current instruments, so the current vegetation algorithms must be modified to work for the new instruments. Users need to know other properties of vegetation, such as *leaf area index* and advanced indicators of vegetation stress, that are not yet produced in a satellite product. STAR will deliver these advanced products for operational use.

Forest Fires

One of the more noteworthy applied research efforts is the ongoing Wildfire, Automated Biomass Burning Algorithm (WF_ABBA) program. Its overall goal is to maintain a global monitoring system that detects fires and characterizes them in real time using geostationary satellite data. The WF_ABBA program strives to monitor hazards, monitor emissions of smoke, assess air quality, and model the presence of aerosols.

When GOES "Rapid Scan" images were collected every few minutes during the fire seasons of 2000 and 2003 in the Western United States, it was obvious that STAR needed to rapidly process and disseminate the fire data from the WF_ABBA system. NWS fire weather forecasters requested faster satellite-derived fire products. Once this capability is developed, STAR will transfer it to NESDIS operations.

STAR collaborated with the fire-fighting community to set priorities on early detection of wildfires in remote locations, daily monitoring of rapidly intensifying wildfires, and monitoring of the day-to-day changes in existing fires. New fire products must be developed for the next generation of satellites. This development will include blending the products from polar and geostationary satellites, as well as from multiple sensors and sources (including ground truth) to improve the fire products.

As new instruments are placed on new satellites, STAR determines their capability for detecting fires. Then the team determines trends in fire activity caused by deforestation, agriculture, and wildfires. Scientists investigate the effects of biomass burning on emission of aerosols and trace gases, land-use change, carbon cycling, climate change, and resource management.

The international community has noted the success of STAR's product for wildfire monitoring and has asked that the monitoring be extended around the world so that fire products would be sent to users in real-time. Climate scientists and land-use experts plan to use data from the European Meteosat satellite and a new Japanese satellite, plus the American GOES satellites, to launch a new global network of fire monitoring.

Aerosols

STAR provides a near real-time product for monitoring air quality to weather forecasters. The Environmental Protection Agency, NWS, and others use the product to track the movement of plumes of pollution and to verify forecasts of air quality.

An example is this GOES satellite image in Figure 23 showing the aerosol optical depth for July 18, 2004. Optical depth is measured by the amount of depletion that a beam of light undergoes as it passes through a layer of the atmosphere. This image shows high values of aerosols (bright red color) and the presence of high particulate loads associated with a smoke plume from biomass burning in the northern Midwest and Canada.

Scientists analyze the optical depth of aerosols (a measure of transparency of the atmosphere) obtained from Earth Observation System (EOS) satellite data, to support the NASA project, "Clouds and the Earth's Radiant Energy System" (CERES). They also evaluate the effects of aerosols on radiation in the atmosphere. STAR scientists will deliver better optical depth data to better assess air quality and to correct the sea surface temperature products.

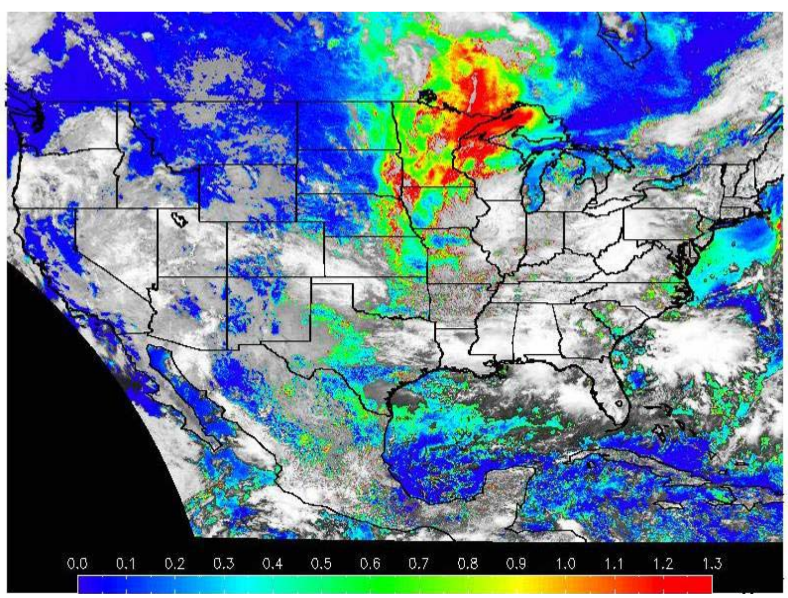


Figure 23. Aerosol Monitoring for Air Quality and Forecasting

The goal of the Aerosol Project is to test a new aerosol algorithm that will retrieve aerosol properties as a function of height over land. This project's long-term objectives are to monitor the forcing of climate change by aerosols, to build long term data sets on aerosols for climate research, and to develop products for monitoring air quality using future sensors on the next generation of NOAA's satellites.

Plans to improve the aerosol products include three elements:

- Separate the contribution of aerosols in the air from the contribution of the land or sea surface to the properties of the observed radiation. Both the surface and the intervening air, with or without aerosols, contribute to the radiation reaching the satellite. This helps to isolate that portion of the radiation that carries information about aerosols.
- Characterize more properties of aerosols. Traditionally, only a few parameters, such as the amount of aerosols, were obtained. Future satellites will carry multi-spectral instruments which can deliver more information on other properties, such as size and shape.
- Obtain the particle size in addition to the total amount (as given by optical depth), and identify the *anthropogenic* portion (of human origin) of the aerosols.

Air Quality

The U.S. Congress directed NOAA to issue nationwide hourly air quality forecasts. NOAA must develop and deploy nationwide forecasts for surface ozone by 2007 and for small particles (smoke and haze) by 2009. There are major uncertainties in forecasts of ozone and small particle concentrations, in part because the prior emission of these pollutants is uncertain.

STAR will develop an advanced algorithm from current satellite sensors to retrieve ozone profiles and small particle concentrations. The resulting products can be directly used to initialize the models of air quality and to diagnose the model outputs. The products will also be used to directly monitor air quality in real time. Eventually, NOAA will have the ability to monitor global air quality from current and future instruments on its own satellites.

Snow Cover

NESDIS produces daily snow maps for several purposes. The maps are used in weather forecasting models, because they provide data needed for forecasting surface temperature and humidity. Snow data are used in hydrological predictions, and are also part of the climate record of snow cover and its change over the long-term. In Figure 24, the white area indicates

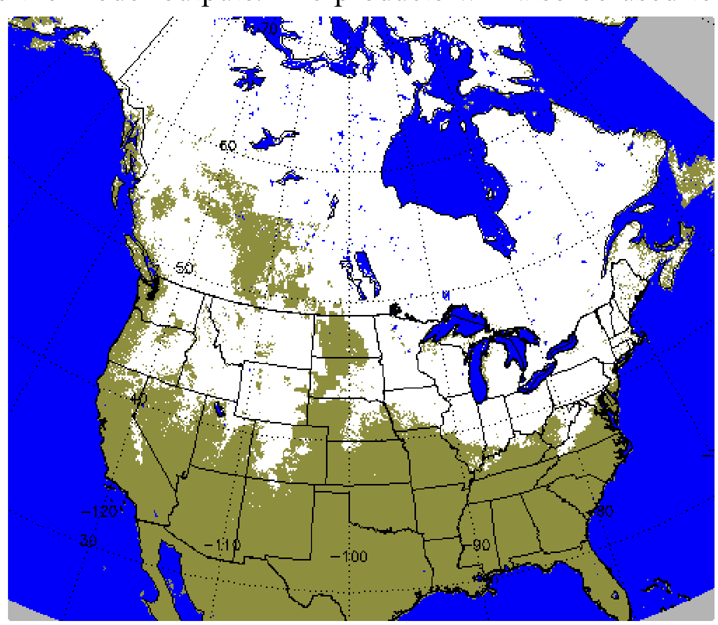


Figure 24. Daily Snow Cover Map by NESDIS for Dec. 14, 2005

snow, while the green area indicates snow-free land. STAR introduced the current NESDIS snow-mapping technology. Over the past 10 years, STAR developed a multi-sensor, multi-satellite snow product.

Future work will include fully automating the drawing of snow cover maps in high resolution, and better describing the snow pack, by monitoring the equivalent amount of water in snow, the properties of the snow (age, grain size), fractional snow cover, and albedo. These properties of snow will be required in advanced models of surface physics for weather forecasting.

All the algorithms for deriving properties of the snow pack will have to be modified for the advanced instruments to be flown on the future NPOESS and GOES-R satellites.

Sea Ice

The Sea Ice Science team creates techniques and products that enable people to estimate the thickness of sea ice from measurement of the height of the ice, using a microwave altimeter on board a satellite. The team is developing three products: accurate daily maps of sea ice over the whole globe at low resolution (data points every 10 km); even better high-resolution tactical monitoring (data every 1 km), but not for the whole globe; and accurate short-term *forecasts* of sea ice from 24 to 120 hours in advance for the whole globe.

Activities	NOAA Performance Objectives	Outcomes
• Develop data products for assimilation into numerical weather prediction models of the National Weather Service • Develop and improve products that provide information on the Earth's environment and are used to predict weather events • Develop and improve products that provide a capability for the National Weather Service to advise the public on air quality and related health hazards	• Increase lead time for weather and water warnings and forecasts • Improve predictability of the onset, duration, and impact of severe weather and flood events • Increase application and accessibility of weather and water information as the foundation for creating and leveraging public, private, and academic partnerships • Increase application and transition of advanced science and technology to operations and services • Increase coordination of weather and water services by integrating local, regional, and global observation systems • Reduce uncertainty associated with decision tools and assessments in weather and water.	• Reduce loss of life, injury, and damages to the economy • Better, quicker, and more valuable information on weather and water to support improved decisions • More customer satisfaction with weather and water services

5.4 Commerce and Transportation

"Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation."

For transportation to be safe in this country, people must identify hazards quickly and warn the operators of planes, trains, ships, and other vehicles, as well as their commercial owners. Satellites are well suited to perform this type of monitoring. STAR has long had a program in monitoring aviation hazards, including icing, turbulence, fog, and convection. The sections below discuss some of the hazards to transportation that STAR is working on.

5.4.1 Products

Aviation Hazards

STAR scientists develop products to detect or forecast several hazards to aviation, including volcanic ash, fog, and low clouds, as well as conditions associated with aircraft icing, turbulence, and convective wind gusts. Figure 25 is an experimental STAR product depicting the height of clouds where icing is likely to occur on aircraft. Although passenger aircraft are safer than ever, society is more vulnerable to these hazards because aircraft are larger and more passengers are flying. This project may substantially reduce loss of life and property.

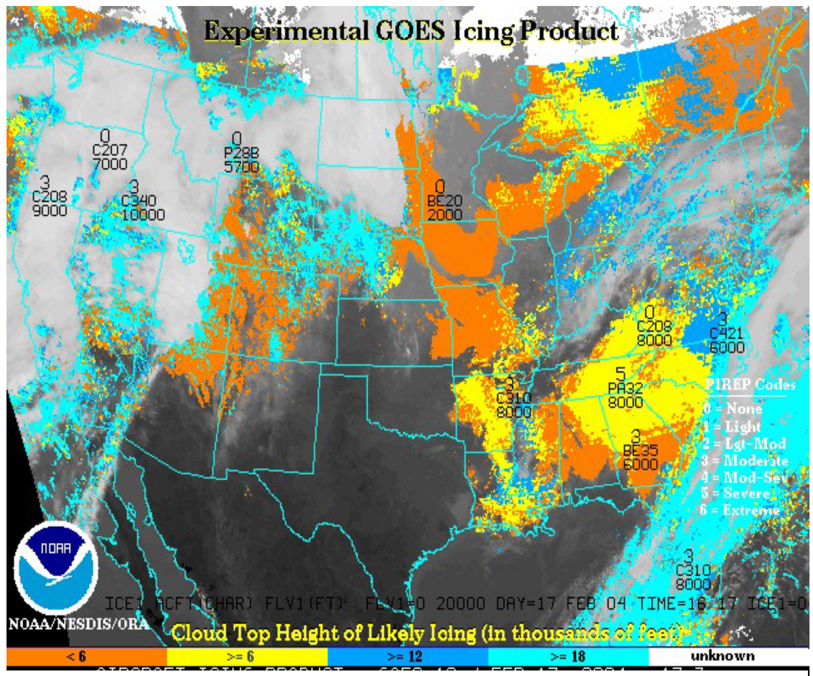


Figure 25. Experimental GOES satellite product for Aviation Icing

Volcanic Ash

Silicate ash emitted by volcanic eruptions travels long distances and threatens aviation by causing serious damage to jet engines and pitting windshields and the edges of aircraft. STAR has shown that multi-spectral data such as the data from MODIS, on NASA's *Terra* and *Aqua* satellites, significantly improves detection of volcanic ash. The false-color image in Figure 26 that includes data from three MODIS infrared bands shows volcanic ash from a 2001 eruption of Mt. Cleveland in Alaska; ash is shown in red, snow and ice in blue, and water droplet clouds in aqua. Since it is vital to know the height and emissivity of volcanic clouds in order to forecast the dispersion of the ash clouds, STAR has improved the retrieval of cloud

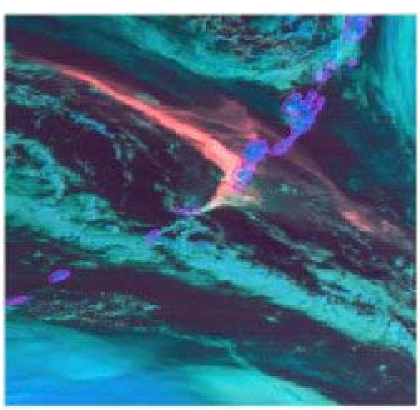


Figure 26. Volcanic ash (in red) on a satellite product using MODIS data.

height and emissivity information using multi-spectral and hyperspectral satellite data. STAR will develop similar products to improve aviation safety using data from the next generations of NOAA satellites.

Ocean Bathymetry

Safe and efficient ship transportation depends on having accurate marine charts that show the bathymetry (the depth of water and the topography of the sea bottom). STAR's Sea Surface Height team analyzes altimeter data from satellites to determine the precise sea level from point to point; this data can be used to add detail to bathymetric charts. The value of satellite altimetry data for detecting submarine hazards is revealed by the marine chart in Figure 27. The submarine *San Francisco* had crashed at the site marked by the large red dot, in a relatively uncharted area distant from sounding information. Combining satellite altimetry data with conventional soundings (black dots), it is now possible to make a chart that shows a submarine ridge less than 500 meters deep running west from the Tarang Reef to the crash site. That ridge was not detected by conventional soundings.

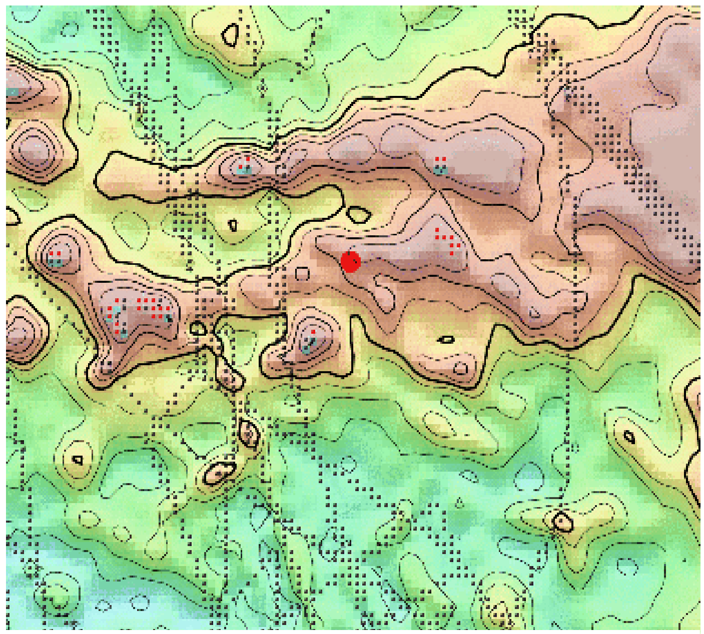


Figure 27. Depth contours of central Pacific Ocean based on both conventional soundings (black dots) and satellite altimetry. Submarine crashed near the large red dot. This chart spans 350 km from left to right.

Sea Ice

The National Ice Center, National Weather Service, and Integrated Program Office have requirements for monitoring sea ice. The Sea Ice science team in STAR creates products for these ice monitoring services. The team's goal is to daily monitor the location, height, and thickness of all sea ice at a resolution of 1 km, using microwave satellites with altimeters. The team also uses Synthetic Aperture Radar (SAR) data from the Canadian satellite *RADARSAT-1* to determine the location, type, and motion of ice on the sea, in lakes and rivers. Ice masks (Figure 28, right) are created from SAR images to monitor sea ice type, concentration, age, motion, and edge location. Ice mask colors correspond to the substrate detected in each image. Knowing the location of the edge of an ice field helps fishing boats, transport, and military vessels navigate safely through icy areas.

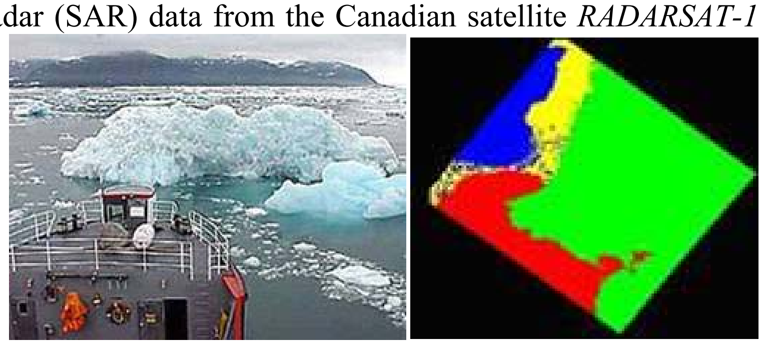


Figure 28. Sea ice photo (left) and ice mask (right)

Using Satellite Wind Measurements to Improve Navigation

High wind speeds are a strong indicator of rough sea conditions. Forecasters are beginning to use satellite-derived wind information to identify safer navigational areas and to provide weather advisories to fishermen and other seagoing vessels. STAR is developing products that will lead to an operational system for several ocean products using SAR. In Figure 29, the Alaskan SAR Demonstration Project maps high-resolution winds in coastal areas and in strong storms. Using algorithms developed by STAR and its collaborators, images (left) from the Canadian satellite RADARSAT-1 are processed for wind speed and direction (right) to identify areas of potential danger.

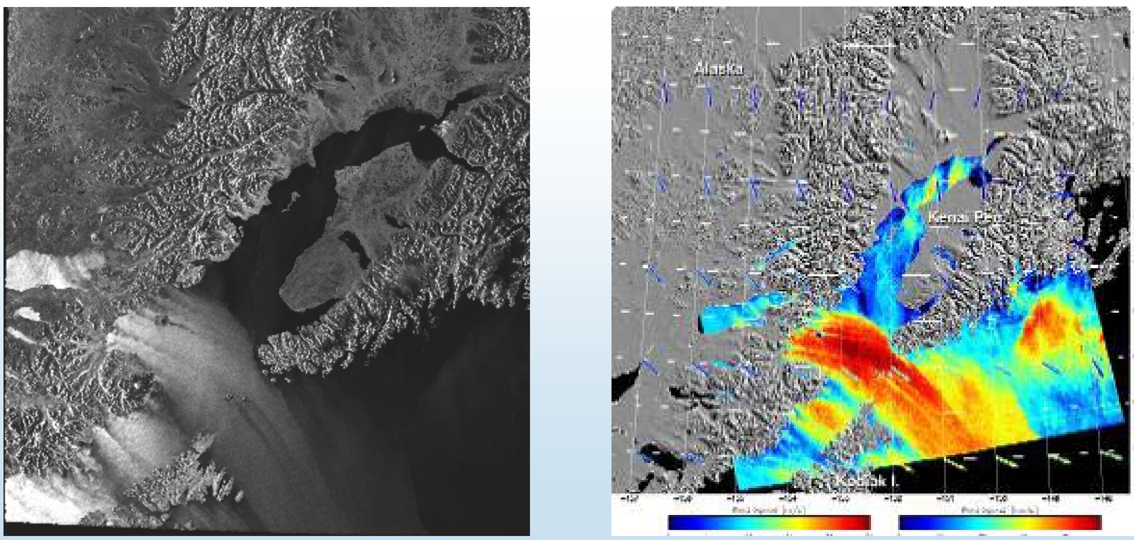


Figure 29. Using Satellite Wind Data to Improve Navigation

Other Ocean Products

SAR radar data will also offer a variety of other types of information about the sea that will be useful to transportation interests. In addition to high-resolution winds, STAR will develop other products from Synthetic Aperture Radar data, including positions of ships and vessels, maps of oil spills, measurements of wave properties, location of features on the sea floor in shallow water, and maps of ice cover on lakes, rivers, and the sea. Many of these products have been demonstrated as experimental, and will eventually become operational in a system that generates sea surface roughness products from an operational satellite with a SAR instrument.

5.5 Critical Support

This strategic goal encompasses support from NOAA Offices that helps NOAA achieve its mission. STAR makes two major contributions in this area:

- Calibrating and verifying operational data from satellites
- Assisting the satellite program offices in the design of satellites and instruments

5.5.1 Design of Satellite Instruments

Next generation of GOES sensors

Center scientists participate in designing revolutionary new instruments that will be flown on the next generation of geostationary satellites and determine the best way to use their data to meet the specific needs of users. There is a large group of users awaiting the new data: from those who forecast short-term weather to those who monitor trace gases and aerosols, land-use, and even climate change. STAR scientists will perform studies on the "trade-off" of one spectral band versus another on the next generation of sounders. Imager sensitivity studies will also continue, as needed.

5.5.2 Build Quality into Data: Instrument Calibration

STAR supports the calibration of all data in NOAA's satellite operations, with the following goals:

To calibrate the operational data on current satellites:

The polar-orbiting satellites in low orbit

  – The imager and sounder in high, geostationary orbit

- To calibrate data that will flow from future NOAA satellites
- To calibrate old data that is re-processed from the archives

To expand current capability in instrument calibration

For example, NESDIS has set up Unified Monitoring of the performance of instruments; STAR teams calibrate instruments on one satellite against instruments on another (inter-satellite calibration); and they link the original calibration of the Infrared (IR) sensors on NOAA satellites to the standard of the National Institute of Standards and Technology (NIST). Work is also being done to routinely compare data between polar and geostationary satellites.

STAR had developed a powerful method to quantify the inter-satellite calibration biases for radiometers on polar-orbiting satellites. If the method were applied to all historic observations from NOAA POES satellites, it would permit the construction of high quality Climate Data Records for climate monitoring and reanalyses. The method is based on observations of a **Simultaneous Nadir Overpass** (SNO). The nadir is the point on the Earth directly beneath a satellite. A SNO occurs when the nadir points of two polar-orbiting satellites cross each other within a few seconds, usually in Polar Regions. At each SNO, radiometer instruments on each pair of satellites view the same place at the same time at nadir, thus eliminating uncertainties associated with the atmospheric path, view geometry, and time differences. Their measurements should be identical. By comparing the measurements of the two satellites during SNOs, it is possible to determine the bias of one instrument with respect to the other.

STAR has created a new standard of quality control for sea surface temperature. The team runs statistical checks to ensure that the sea surface temperature products are consistent, and verifies them against ground truth data observed by buoys and ships.

5.5.3 Support NOAA Satellite Risk Reduction Programs

With the launch of the next generation GOES-R satellite expected after 2012, NOAA will begin a new era of remote sensing from geostationary satellites. The users of the new information include weather forecasters, developers of weather predictions models, and scientists studying aerosols and trace gases. Some of the new instruments on board the new series of satellites include an advanced imager, advanced sounder, an imager of coastal waters, a lightning mapper, a solar imager, and a space environment monitor. Perhaps the boldest new instrument is the Hyperspectral Environmental Suite (HES). Using this instrument, NOAA will be able to produce three-dimensional depictions of atmospheric temperature and moisture with sharper vertical resolution, horizontal resolution, time resolution, and greater coverage of the surface. The HES-Coastal Waters instrument uses information from a wavelength of light shorter than present instruments use. This capability will tell us about different properties of ocean, coastal, and land surfaces.

A new imaging instrument, the Advanced Baseline Imager (ABI), will cover a greater area of the surface at more frequent time intervals and will use more channels. The ABI will allow continuation of current products and also a host of new and improved products.

STAR supports two Risk Reduction Programs in NOAA: the "NPOESS Data Exploitation" for polar-orbiting satellite data and the GOES-R program for geostationary data. The main goal of the HES data compression project is to offer a flexible solution to handle the large data rates of the next generation of geostationary sounders. STAR can accomplish this by being the leader in the field of high spectral resolution infrared data and by finding the effects of data compression on all of the products derived from the data.

5.5.4 Support NOAA Data Programs and Committees

The GEOSS initiative has led NOAA to participate in many other interagency and international programs on Earth observation. NOAA is preparing an Integrated Global Environmental Observation and Data Management System, for the Integrated Earth Observing System (IEOS). NOAA may also play a role in the Integrated Ocean Observing System (IOOS). Finally, NOAA is the lead federal agency for climate research under the national Climate Change Science Program.

Since the integration of systems and data will yield better products, integrated systems such as the three mentioned above are central to NOAA's mission goals. STAR contributes to all of these new systems as our people create, implement, and maintain them.

After the White House recently published a U.S. Ocean Action Plan, Congress considered legislation to redefine a national Ocean Policy. A new Policy would elevate NOAA's role in ocean research and make it the primary federal agency providing ocean data and products. Satellite observations of the oceans are rapidly becoming an important source of information for NOAA's expanding role in coastal and ocean services.

5.5.5 Improve the Use of Satellite Data to Support the NOAA Mission

Hydrological Cycle Products

STAR will collaborate with the Office of Satellite Data Processing and Distribution to develop operational products for the hydrological cycle from passive satellite microwave data.

Some of the most important products are precipitation rate, total precipitable water, liquid water path and ice water path in clouds, snow cover, equivalent water in snow, sea-ice concentration, and land surface temperature. STAR will improve the physically based algorithms for all these products as they are modified to use the data from new sensors on the upcoming generation of polar-orbiting satellites, including Metop, NPP, and NPOESS.

Geostationary (GOES) Imager and Sounder Products

The current generation of geostationary satellites (GOES) generates many products from both the imaging and sounding instruments. STAR will improve them and generate new products for weather forecasters and developers of weather prediction models as well as for the aviation industry, university scientists, other government agencies, and international institutions. To "master the present," STAR will strive over the next five years to better use the capability of the current suite of GOES satellites, to better depict the true state of the earth-atmosphere system, especially on shorter time scales that are not observable by polar-orbiting satellites. STAR also participates in putting stand-by satellites into operational use, and in checking-out instruments on new GOES satellites.

Satellites traditionally used for monitoring daily weather must be inter-calibrated before they can be used in longer-term monitoring of the regional or global environment. Thus, it is now increasingly important to compare the radiation measurements from different instruments on different satellites. The main goal of the inter-calibration effort is to compare the radiation measurements from the high-orbit geostationary satellites and the low-orbit, polar-orbiting satellites.

STAR is investigating problems that have degraded the quality of some operational products. To do this, STAR plans to verify the accuracy of existing and new products; maintain parallel processing of experimental products; and follow a robust and repeatable path for passing new algorithms and products from Research and Development (R&D) into routine operations.

STAR will develop a new system for sounding the atmosphere, based on the hyperspectral sounder, for the next-generation of geostationary satellites, starting with GOES-R.

Sounding the Atmosphere from Low Orbit

When sounding the atmosphere, the goal is to measure the properties of the air in a vertical column from the top of the atmosphere down to the surface. The typical properties measured are the temperature and the moisture content at many levels. One of the challenges of doing this from space is the need to distinguish cloudy views and partly cloudy views from clear-sky views.

The best atmospheric soundings are obtained from the clear-sky views, where one is confident that no clouds are present and where one can infer temperature, moisture, and other properties all the way down to the surface. The process of finding the clear-sky views is sometimes called *hole hunting*. Fortunately, when microwave data are available, as on the polar-orbiting (POES) platforms, one can achieve the desired result with two partly cloudy scenes as long as the percentage of cloud cover is different in the two scenes. This procedure of winnowing the data to infer what an atmospheric sounding would look like in a clear-sky view is called *cloud clearing*.

The best atmospheric soundings today come from the AIRS on the NASA satellite *Aqua*. It is the first atmospheric sounder producing a great amount of detail in the observed wavelengths (this is called *high spectral resolution*). Among other benefits, such detail may allow us to better probe the properties of many vertical layers and to distinguish more layers and more vertical structure. It also allows measurements of trace gases such as carbon dioxide. In Figure 30, the percentage errors of the AIRS sounding (blue curve on the left) are significantly smaller than the errors of the now-operational Advanced Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (ATOVS) sounding (yellow curve on the right). These soundings measure the amount of water vapor in the low and middle atmosphere. The diagram depicts the percentage error of the water vapor measurement; the black dashed line indicates the maximum error acceptable.

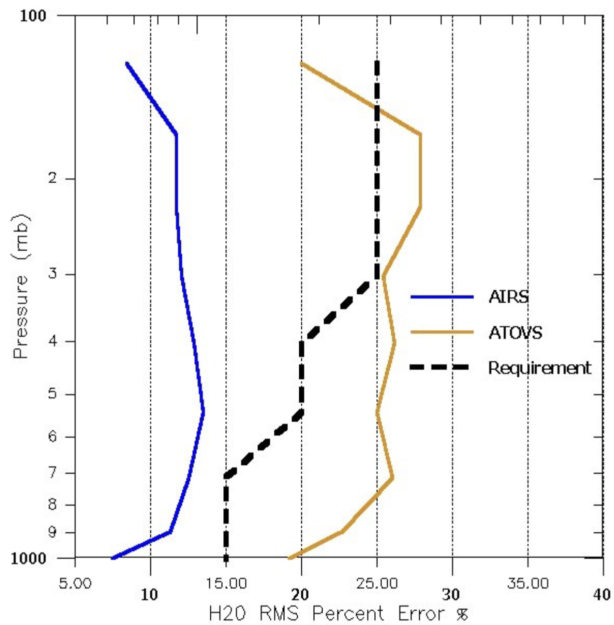


Figure 30. Error comparison of two instruments (AIRS and ATOVS) at various heights (pressures) in the atmosphere.

The AIRS science team has invested a large effort in creating a research algorithm for AIRS data. STAR is now in a position to use the AIRS algorithm and resulting suite of products for the next two generations of NOAA's operational satellites.

Cloud Clearing

The AIRS science team has selected cloud clearing as its primary method for obtaining clear-sky soundings of the atmosphere after having invested many resources to develop algorithms and verify the results. These results are called *cloud-cleared radiances* (CCRs). The CCR products are computed from a clear-sky estimate that is derived from a microwave instrument, the Advanced Microwave Sounding Unit (AMSU), because microwave sensors can generally see through clouds. Any uncertainty in the AMSU instrument degrades confidence in the end results; if the AMSU fails, no soundings can be produced. Therefore, the team will also investigate at least five other approaches to obtaining cloud cleared radiances; the other approaches do not require microwave data.

The procedures described above use low-orbit, polar-orbiting satellite data. However, these efforts may help us to achieve the very desirable goal of sounding the atmosphere from a high-orbit, geostationary satellite like GOES. The next generation GOES-R is now being designed; unfortunately, it appears that it will fly without a microwave instrument. Instead of using microwave data, STAR will explore whether data from the GOES imager or from weather forecast models can provide the cloud clearing first step for the GOES-R infrared sounder. Because it is unlikely that there will be a microwave instrument on the GOES-R, the innovative techniques being explored for all three generations of the polar-orbiting sounders—the present AIRS system and the future systems described in the next two sections—will be of fundamental value.

In the near future—the European sounder

NOAA/NESDIS expects to see a lot of benefits from closely cooperating with the European Community on using their new atmospheric sounding instrument, the Infrared Atmospheric Sounding Interferometer (IASI). It is scheduled for launch in 2006 on the European Metop satellite. With thousands of channels (about 8,600), it has the potential of providing extremely detailed observations of atmospheric properties in the vertical direction. In addition, all of the sounding instruments presently used on the operational NOAA satellites will be placed on the Metop satellite. This action allows good cross-calibration between the current operational sounders and the experimental IASI sounder.

To realize these benefits from the European instrument, STAR will undertake three actions:

- Compare the results from the present NASA instrument (AIRS) and the future European instrument (IASI) by simulating the data that IASI will generate, and using lessons learned from prior experience with simulations of AIRS data
- Use images from the current NOAA polar-orbiting satellites to be certain that the zones that appear to be cloud-free are really free of clouds on the images
- Use imagers either on the same satellite or on co-located NOAA satellite images, to provide cloud-clearing, and thus to calibrate the sounding data from the IASI instrument

In the longer term, NOAA will have a new sounder

NASA will launch a new sounding instrument, the Cross-track Infrared Sounder (CrIS), in 2009 on the NPOESS Preparatory Project (NPP) satellite. Then, the inter-agency coalition running the NPOESS project, which includes NOAA, will launch operational instruments on satellites in 2012 and 2014. The CrIS instrument is much like the current, experimental AIRS system. STAR will inter-compare the atmospheric soundings to be obtained from the three different instruments mentioned above (AIRS, IASI, and CrIS). The plan is to extend the intercomparisons between the IASI results and the AIRS results that will be done in the near term, as mentioned in the previous section. In addition, there will be a cloud imager on the future NPP and NPOESS satellites that will enable benefits from years of prior experience with cloud clearing.

Cloud Images from Polar Orbiting Satellite Data

The operational branch of NESDIS, the Office of Satellite Data Processing and Distribution (OSDPD), needs an improved system for processing the images from the current polar-orbiting satellites. Therefore, STAR will design a front-end processor that will deliver multiple product lines to various parts of NESDIS. The system of products is called Clouds from AVHRR (CLAVR)*,* where AVHRR is the current imaging instrument on these satellites. One benefit will be to have real-time global analysis of cloud properties for multiple layers of clouds.

In order to produce research quality data for long-term climate studies, the archived images from the old AVHRR instruments will have to be recalibrated and perhaps renavigated. STAR will upgrade the quality of data from many years of these images and try to match the higher level of detail expected in the images from the European Metop satellites, to be available soon.

The next generation of polar-orbiting satellites, the NPP and NPOESS, will generate very detailed images from a set of instruments called the Visible/Infrared Imager and Radiometer Suite (VIIRS). In order to be ready for these data, STAR will investigate how best to use the data from the experimental imager (MODIS) and sounder (AIRS) on the current *Terra* and *Aqua* satellites. STAR will address current concerns about the performance of the cloud product from VIIRS to ensure that all cloud products are optimal, perhaps by a smart combination of these images with data from other instruments on NPOESS.

Outgoing Long-wave Radiation (OLR)

A long-term record of outgoing long-wave radiation from the Earth is extremely important to studies of climate change and other topics in climate science. STAR is developing a long record of outgoing long-wave radiation from the three generations of sounding instruments described above (High-Resolution Infrared Radiation Sounder [HIRS], AIRS, and CrIS). Furthermore, this data record should be compatible with the Earth Radiation Budget System (ERBS) data that will be available on future NPOESS satellites. The estimates will be much improved over the long-wave measurements now available.

The immediate plans are to complete the production of operational OLR data from the HIRS instrument, by calibrating and adjusting a complete record from all satellites that have had the HIRS. STAR will also evaluate a new, independent set of data from a NASA project called "Clouds and the Earth's Radiant Energy System."

Activities	NOAA Performance Objective	Outcome
• Provide instrument expertise to the new satellite programs at the Program Offices for polar-orbiting (NPOESS) and geostationary (GOES-R) satellites • Calibrate and verify operational satellite data.	• Increase the quantity, quality, and accuracy of satellite data that are processed and distributed within a targeted time.	• Secure, reliable, and robust information flows from NOAA to the public.

5.6 NOAA Cross-Cutting Priorities

5.6.1 Education and Training

STAR has the mandate to improve the use of satellite observations. One factor that limits the utility of satellite observations in weather forecasting and other areas is that users lack the knowledge on how to use these observations. Training and education are necessary to ensure that the forecasters understand how to use the data in the best possible manner. Given the huge amount of new satellite information that will become available in the next decade (especially by the next generation of satellites—NPOESS and GOES-R), education and training programs must accelerate so that new satellite products are easily understood and accepted as they become available. STAR provides education and training to users in two ways:

- The Virtual Institute for Satellite Integration Training (VISIT) has been highly successful in training operational forecasters directly through a web site. It has provided over 15,000 hours of training since 1999. STAR continues to provide new training sessions in VISIT.
- The WMO has set up the International Virtual Laboratory (IVL) as its method to provide satellite training material, datasets, and satellite analysis tools via the World Wide Web.

STAR supports this program through its Cooperative Research Programs. The training is in the areas of tropical cyclones, severe weather, and mesoscale forecasting. This program also trains the National Weather Service on the use of satellite data available on their Advanced Weather Interactive Processing System (AWIPS).

Although the VISIT program has been highly successful, the agency needs more in-depth training on the best use of current and planned satellites. Two institutes of the Cooperative Research Program are developing the new Satellite Hydrology and Meteorology training program with the NWS training branch.

The other type of training that is so necessary is the formation of professionals in satellite data utilization. Through close collaboration on-site with outstanding university graduate programs in atmospheric and oceanic science, STAR's Cooperative Research Program is achieving this goal.

5.6.2 Information Technology

In May 2005, STAR conducted a week-long work session on IT Infrastructure. The study group represented STAR, its Cooperative Institutes, private-sector partners, and other science partners. The report describes the group's recommended changes for IT Enterprise Architecture and IT Governance in STAR. The goal is to have an IT Enterprise Architecture that meets its future computing requirements. STAR will design a single, flexible, and secure networked environment that improves the flow of data from satellites, through data processing, to distribution to customers.

By the end of 2005, STAR established its IT governance. Four groups help the Deputy Director govern IT: an IT advisory committee, a data management group, a configuration management group, and a web services group. These groups will put the recommendations in practice from 2005 to 2007.

5.6.3 Research to Operations

STAR needs to reduce the time it takes to transfer research products into operations. More efficiency in IT will be the answer. In order to improve the communication between these two groups and draw upon the right mix of experts, the IT Study Group recommended that STAR adopt configuration management software and Integrated Process Teams.

5.6.4 Science Management

Every year, STAR prepares three levels of planning documents: this STAR Road Map, providing an overview for the entire Center; the Division Road Maps, which provide more detail for each Division's activities; and the Research Project Plans (RPP), which provide specific details on each science project. This Road Map is an initial step to identify Center activities for the next five years that support NOAA strategic goals and the requirements of global customers. The Division Road Maps describe each Division's requirements, scientific research priorities, customers, partners, resource needs, and ways of measuring success. The lead scientists for each science project prepare the RPPs to describe key aspects of their research for the next five years. Appendix A lists all of the Research Project Plans.

In keeping with the Government Performance and Results Act and NOAA's new framework for planning and executing its programs, STAR is defining a new model for managing its science activities efficiently. STAR is now using two new tools:

- **Research Project Summaries**. The summaries describe, at a glance, the goals and tasks of a science project, as well as performance measures to judge success and milestones to measure progress.
- **Performance Goals and Measures Matrix**. STAR now has a matrix of performance goals, measures, and milestones. The matrix connects the performance goals to funding sources, outcomes, and requirements, to help manage the priorities and activities of the Center.

STAR can now track its activities and provide answers about its organization on short notice.

6 Performance Goals and Measures

STAR has developed performance management tools to align activities with NOAA's strategic planning process. The first step in NOAA planning is to develop a strategic plan and strategic goals. Once that has been accomplished, STAR aligns its priorities and activities with NOAA's stated goals. NOAA also develops performance measures for its programs that attempt to achieve strategic goals. At a high level, the goals of STAR are as follows:

- Meet customer requirements
- Build quality into satellite data
- Help customers achieve their performance goals

STAR also develops quantitative indicators to measure the success of what it does. Here are two examples:

- Correlations between a forecasted parameter (like tomorrow's wind speed and direction) and a parameter actually observed tomorrow (a high correlation would suggest that the STAR product improved the accuracy of the forecast.)
- Percentage of STAR products transferred from research to operations

STAR has identified twenty performance goals, identified in the table below. Each goal is associated with a measure of performance.

STAR Unique Performance Goals and Measures

No.	NOAA Goal	NOAA Priority	Performance Goal	Performance Measure
1	WW	IGEO	Develop new sources of data for assimilation into numerical weather prediction models	Number of new data sources actually assimilated into weather models
2	ALL		Using satellite data, develop products which support NOAA mission	Number of new or altered products transferred to operations
3	ALL		Using satellite data, develop techniques which support NOAA mission	Number of new techniques transferred to operations
4	CS	SS	Review instrument specifications for satellite acquisition programs	Number of design reviews and number of comments
5	CS	SS	Calibrate new instruments designed for satellite acquisition programs	Number of new algorithms developed to calibrate new instruments
6	CS	SS	Reduce risk in new satellite systems	Number of contributions to programs
7	CS		Build quality into NOAA satellite data	Number of algorithms changed to improve calibration
				Number of data sets validated
8	CS		Develop accurate, long-term data sets for research	Number of climate data records completed
9		WF	Build and sustain a skilled workforce	Improved ratio of hires/vacancies
				Improved ratio of skill hires/skill requirements
				Number of management tools implemented
10		IGEO & DM	Support NOAA Data Programs and Committees	Number of committee contributions
11		EL	Educate and inform the public and special interests on the use of satellite data and related research	Number of education and training activities
12		EL	Publish quality papers which describe STAR research and advancements	Number of papers published
13		EL	Develop training tools which can be used for satellite education	Number of training tools developed
14		EL	Provide training on satellite applications	Number of students trained
15		EL	participate in national, international conferences	Number of conferences attended
16		IL	Support national and international committees which promote integration and use of satellite data	Number of committees supported
17		IL	Share satellite data and information among international partners	Number of cases sharing data/information with intl. Partners
18	CS		Improve "Research to Operations"	Number of R2O efficiencies implemented
19	CS		Improve STAR IT Management	Number. of IT efficiencies implemented
20	CS		Improve STAR Management of Science	Number of management tools implemented
				Decrease monthly percentage deviation from spending plan

Goals:
WW = Weather and Water
CS = Critical Support
ALL = All five NOAA goals

Priorities:
IGEO = Integrated Global Environmental Observation
SS = Ensure sound, state-of-the-art research
WF = Work force
EL = Environmental literacy
IL = International leadership

7 Enablers and Constraints

7.1 Advances in Satellite Technology and "Risk Reduction"

The simple truth about satellite technology is that the work will never be finished; improvements are always made on future suites of satellite instruments, and the complex requirements of users always change. In order to prepare for new upgrades, STAR must continuously investigate new technology to identify gains and risks if the instrument is flown on future satellites. Among the advanced technologies that STAR scientists and engineers are investigating are Doppler Wind Lidar, Global Positioning System radio occultation, and Synthetic Aperture Radar (SAR).

Satellite technology for Earth observation will go through three major upgrades in the next 15 years: a new generation of geostationary satellites (GOES-R), a new generation of polar-orbiting satellites (NPOESS), and a new generation of atmospheric sounding instruments based on hyperspectral sensors like the Atmospheric Infrared Sounder (AIRS). Formerly separate civilian and military technologies are being combined; the programs of individual nations are increasingly assumed by international partnerships. NESDIS has collected extremely useful data about the planet since the 1960s, and understanding of the Earth has grown as information of higher quality and detail has been collected from satellite platforms. These improvements will continue.

Whenever a new sensor is identified or proposed, STAR investigates its capabilities and limitations. STAR simulates the output of the proposed instrument in computer models and searches for errors that it might produce. In addition, the developers might test its performance on an aircraft or on other satellite missions.

By collaborating with users (such as organizations that create weather prediction models), STAR can test these simulated data sets to assess the possible results of these new observations being available on operational computer platforms. The findings improve the design and evaluation of future sensors and ultimately reduce the risk of costly future satellite missions.

7.2 Visualization

In 2004, the NESDIS Environmental Visualization Program (EVP) became a reality for STAR, but its possibilities are just beginning to be appreciated. The goal of EVP is to augment what scientists can do with satellite data through advanced techniques of visualization. EVP uses geographical information system (GIS) technology to project images from geostationary satellites and polar-orbiting satellites and to add layers of information over the imagery. Most products in STAR consist of layers of information taken from the various channels of data from the GOES and POES satellites, so GIS technology can really enhance the use of this information.

7.3 Advances in Information Technology

While advances in the technology of satellites and sensors are a great step forward, Information Technology (IT) really enables society to benefit from huge volumes of satellite data. STAR must migrate towards the computational technology that can process, reprocess, and make sense of the data from the next generation of new satellites. Tomorrow's sensors will demand a lot of networks and data storage. In order to transfer the results of research into operations more quickly, it is necessary to simulate complex data sets and utilize multiple processors for complex operations. STAR's IT specialists must also anticipate the growing problem of information security to ensure that the Center's computers and data remain available.

Once scientists have products from the satellite technologies of tomorrow, the information they contain must be visualized on computer systems that can handle these much larger data sets, and then distributed. Two ways that the staff at STAR can make sense of the new products, verify their accuracy, and distribute the meaningful content to end users are:

1. To exploit three-dimensional (3D) visualization programs
2. To use enhanced geographical informational systems (GIS).

The web-based training program also teaches the use of enhanced satellite technologies and products.

New and improved technologies permit scientists to create new and improved products. STAR uses IT to increase its abilities to process and experiment with larger amounts of data in shorter periods of time. New sensors create new possibilities for research and for products. As these possibilities unfold, STAR serves more customers with a wider range of needs.

7.4 Scientific Techniques

A single instrument or a single satellite with many instruments cannot measure the pulse of a planet. The world needs a coordinated network of satellites, in various orbits, with many types of advanced instruments, each of which communicates data quickly. The Center has the large and never-ending task of calibrating these instruments. This is accomplished by calibrating each individual instrument to an internationally recognized standard; then instruments on the same satellite are cross-calibrated with each other and with other satellites in the same orbit. Finally, different instruments in many different orbits and paths are calibrated. The STAR calibration team has been calibrating NOAA polar-orbiting and GOES geostationary satellites for decades. Building from that expertise, STAR will ensure the stability and quality of the future network of global satellite observing platforms.

Good calibration of remote satellite measurements gives the Nation better warnings of natural hazards and better forecasts of natural phenomena. STAR gives people the most accurate information available so that their own missions may be equally successful.

Centralized processing and merging of all global observations has benefits:

- It allows STAR to serve new users and to understand their requirements for new products.
- The staff can better assess the state-of-the-technology and select the right sensors for tomorrow's satellite missions.
- Technicians can evaluate the impact that data from future sensors might have on current products.
- Decision makers can use STAR to find the best solution.

STAR scientists need improved access to global observations from conventional, non-satellite sources to ensure that STAR's satellite products are offering correct information. The probability that each satellite observation is sound can then be quantified by assigning a confidence factor that is based on comparisons of satellite data with ground truth. By combining satellite products with other observations, STAR will be able to deliver a single optimized product.

8 Impact on Society and NOAA Goals

STAR's applied research contributes to world-wide social and economic benefits that affect these international activities:

- Fishing
- Shipping freight by air, sea, and land
- Aviation
- Public broadcasting
- Health and human services
- Agriculture
- Natural resources management
- Emergency management
- Homeland security
- National defense
- Scientific research

STAR serves the organizations that service these industries, by creating new information products and enabling customers to use new data. NOAA now embraces more cross-disciplinary approaches to understand the physical and biological processes on Earth. STAR benefits the world by:

- **Air Quality Monitoring**: STAR provides real-time observations that allow other specialists to make accurate forecasts. These enable society to mitigate the health effects of poor air quality by managing transportation demand and reducing energy use days in advance.
- **Ocean Observations**: These data are essential inputs to accurate climate forecasts. Using ocean observations from STAR, specialists may be able to predict long-term drought.
- **Water Quality Monitoring**: Real-time water quality data for every watershed and coastal area could provide farmers with the information they need to apply the correct amount of fertilizers and pesticides to maximize crop yield at the lowest cost. The intention of these data is to support both healthy ecosystems, increased yields from U.S. fisheries, and coastal tourism.

Natural disasters cost society a great deal. Everyone from farmers to emergency managers need advance information to plan their responses and relief activities. The effects of events such as hurricanes, forest fires, summer urban heat emergencies, and erupting volcanoes demonstrate that the United States benefits from tools that protect the population and commerce of the Nation. Data from U.S. satellites are turned into analyses, assessments, forecast guidance, situational outlooks, and mitigation plans that address these natural hazards.

Numerical weather prediction benefits directly from the products and services of STAR. Improved surface temperatures and moisture forecasts have had a significant impact on the energy industry. But there is more: with better temperature forecasts, farmers can prepare for freeze outbreaks in the deep South, where surprise freezes cause huge losses in crop production. And highway managers can plan to deploy sand and salt well in advance of a surface icing event that would otherwise endanger the safety of motorists.

Ultraviolet (UV) radiation from the sun is a growing concern to the public as levels of UV have increased in recent years due to decreasing amounts of ozone in the stratosphere. The effects of UV radiation on the Earth's ecosystems are not completely understood. While humans can choose to protect themselves, plants and animals are not so fortunate. Increased UV radiation can cause significant damage to small animals and plants. Marine phytoplankton, fish eggs, and young plants with developing leaves are vulnerable to damage from overexposure to UV radiation. Clouds and ozone have a large effect on UV radiation levels, but cloudy skies do not offer enough protection from UV radiation. Satellites easily monitor clouds, cloud height, ozone levels, and other factors that affect the intensity of UV radiation. STAR research on monitoring UV radiation from satellites takes account of all of this and delivers a single UV product.

The international scientific community has discovered that fires set by humans impact the regional and global climate and play a major role in the global carbon cycle. These fires (biomass burning) alter the radiative balance of the Earth. The extent of burning and its global effects are not well understood. Remote sensing offers the most cost-effective way to monitor fires, smoke, haze, and aerosols, especially over the long term.

Finally, a National Academy of Sciences Report on Emerging Infections recommended that the Public Health system "increase the use of novel surveillance systems and modeling techniques to help predict or monitor disease trends, environmental and climatic conditions or genetic shifts that suggest disease outbreaks." When STAR identified potential outbreaks of the West Nile Virus, it was putting these recommendations into practice.

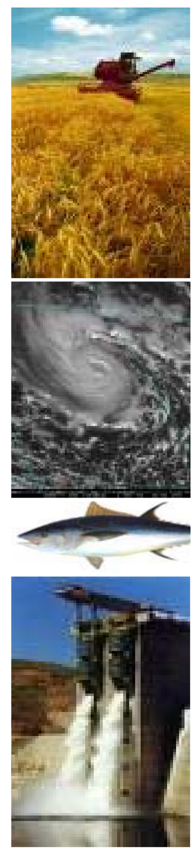
9 Summary

Remote observations from satellites are the most cost-effective way to monitor the global environment. The Center for Satellite Applications and Research, STAR, has organized its scientific research and development in a way that assists NOAA and the nation in meeting the five strategic goals of NOAA in climate, ecosystems, weather and water, commerce and transportation, and critical support for NOAA's mission.

STAR supports a host of activities in remote sensing that improve the understanding and monitoring of Earth's environment. Drawing upon new ideas in instruments, techniques, and processing methods, STAR creates a suite of new products, expands the scope of existing products, and turns the products into tools for easy transfer into practical applications inside and outside the U.S. Government.

Figure 31
STAR's applied research is ultimately measured by nine societal benefits. These areas guide the vision of STAR's program:

- **Improve weather forecasting**
- **Reduce loss of life and property from disasters**
- **Protect and monitor our ocean resources**
- **Understand, assess, predict, mitigate, and adapt to climate variability and change**
- **Support sustainable agriculture and combat land degradation**
- **Understand the effect of environmental factors on human health and well-being**
- **Develop the capacity to make ecological forecasts**
- **Protect and monitor water resources**
- **Monitor and manage energy resources**



Appendix A: Research Project Plans in STAR

The Research Project Plans of the **Satellite Meteorology and Climatology Division** (SMCD) are:

- Vegetation Health and Fraction products
- Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model, Developed for Satellite Data Assimilation and Climate Applications
- GOES Surface and Insolation project
- Development of a CERES Outgoing Long-wave Radiation (OLR) Data Set , Compatible with Current Operational OLR Data: A Pre-NPOESS Risk Reduction Study for the CERES Instrument
- Radiance Products and Atmospheric Soundings from Advance Infrared and Microwave Sensors for Weather and Climate Applications
- Precipitation and Floods
- Polar Operational Science Support for Temperature and Water Vapor Atmospheric products
- Satellite Ozone
- Active Sensors for Atmospheric Sounding from Satellites
- GOES Surface Ultraviolet Radiation product
- Current GOES Sounder products
- Calibration and Instruments
- Aviation Hazards
- Air Quality
- Aerosol Remote Sensing from Operational Satellites

The **Satellite Oceanography and Climate Division** (SOCD) is divided into six Science Teams, each with a Research Project Plan that focuses on three or more different projects. In addition to the Teams, the Division hosts the CoastWatch/OceanWatch and the Coral Reef Watch programs.

- Sea Surface Temperature Science Team
  - Environmental Data Records
  - Climate Data Records
  - SST Quality Control and Quality Assurance, Calibration and Validation
  - SST Applications

- Sea-Surface Roughness Team, Synthetic Aperture Radar (SAR) Research and Development
  - Secure SAR Data Access for Research and Operations
  - SAR product research
  - SAR Applications Demonstrations and User Outreach and Education
  - Operational SAR Ocean products system development

- Sea Surface Height Team
  - Altimeter Data Sets
  - Ocean Dynamics
  - Marine Gravity and Bathymetry
  - Climate

- Ocean Color Science Team
  - Marine Optical Buoy (MOBY)
  - Marine Optical Characterization Experiment (MOCE)
  - Ocean Color Validation
  - Ocean Color Applications
  - Optical Water Mass Classification

- Ocean Surface Winds Science Team
  - Microwave Scatterometry
  - Microwave Radiometry
  - Air-Sea Interaction
- Sea Ice Team
  - Sea Ice product research and development
  - Sea Ice Altimetry
  - National Ice Center Polar Research
- Ocean Remote Sensing External Research
- CoastWatch/OceanWatch
- Coral Reef Watch

The **Cooperative Research Program** (**CoRP**) has written the following Research Project Plans:

- Current GOES Science and Data Validation
- GOES-R Advanced Baseline Imager (ABI) / Hyperspectral Environmental Suite: Science, Data Compression, and Risk Reduction
- GOES Surface and Insolation Project (GSIP)
- MODIS Polar Winds
- Cloud Research from Polar-Orbiting Imagers (VIIRS, CLAVR, PATMOS)
- Geostationary Satellite **W**ild-**f**ire **A**utomated **B**iomass **B**urning **A**lgorithm (WF_ABBA)
- Interannual Variability of Oceanic Phytoplankton, Biomass and Productivity: Project Predicting Marine Organisms
- Advanced Precipitation Algorithms: Consolidated Microwave Hydrological Products—Global Precipitation Climatology Project
- Application of Remote Sensing in the Detection and Monitoring of West Nile Virus
- Mesoscale and Severe Weather: Research and Applications Development
- Tropical Cyclone / Satellite Research and Application Development
- Satellite Training and Outreach

STAR priorities drive the research of CoRP. Each Cooperative Institute submits proposals to STAR for review. A grant of funding is then given to the Cooperative Institute to conduct the research described in approved proposals. The grants fund a project for one year. Grants for continuing research must be applied for each year. The Cooperative Institutes are conducting the following research:

Cooperative Institute for Meteorological Satellite Studies—CIMSS

- Participation in the GOES Improved Measurements and Product Assurance Plan
- CIMSS Participation in GOES R Risk Reduction
- CIMSS Research Activities in the NOAA Ground Systems Program
- Development of a Secondary Eyewall Formation Index for Tropical Cyclone Intensity Forecasting
- CIMSS Hyperspectral Data Processing Demonstration
- Radiance Calibration/Validation, Cloud Property Determination and Combined Geometric plus Radiometric Soundings for the National Polar-orbiting Operational Environmental Satellite System (NPOESS)
- Ongoing Satellite Data Impact Studies in the Global Forecast System, Including MOWSAP2 (MODIS Winds) and AIRS Radiance Assimilation Experiments

- CIMSS Research Activities in Support of Topics in Geostationary and Polar Orbiting Weather Satellite Science
- CIMSS Participation in Satellite Hydro-Meteorology (SHyMet) Training
- CIMSS Studies in Satellite Navigation and Climate
- CIMSS Research Activities for the VISIT Program

Cooperative Institute for Research in the Atmosphere—CIRA

- Science Stewardship of Thematic Climate Data Records - A Pilot Study with Global Water Vapor
- Research and Development for GOES-R Risk Reduction, for Mesoscale Weather Analysis and Forecasting
- CIRA Activities and Participation in the GOES Improved Measurements and Product Assurance Plan (GIMPAP)
- Development of a Multi-platform, Satellite Tropical Cyclone Wind Analysis System
- Development of an Annular Hurricane Eyewall Index for Forecasting Tropical Cyclone Intensity
- Development and Evaluation of GOES and POES Products for Analyses of Tropical Cyclones and Precipitation
- Getting Ready for NOAA's Advanced Remote Sensing Programs: A Satellite Hydro-Meteorology (SHyMet) Training and Education
- Support of the Virtual Institute for Satellite Integration Training (VISIT)
- Improved Statistical Intensity Forecast Models
- Continued Development of Tropical Cyclone Wind Probability Products

Cooperative Institute for Climate Studies—CICS

Global Energy and Water Cycles:

- Assessment of the Global Precipitation Climatology Project
- Land-Ocean-Atmosphere Interaction and Rainfall Variability in the Tropical Atlantic Region
- Use of Microwave Satellite Products for Hurricane Forecasts

Climate Diagnostics:

- Improving Forecasts of Land falling Hurricanes
- A Link between Tropical Precipitation and the North Atlantic Oscillation
- Variability of Precipitation Associated with the North American Monsoon

Remote Sensing and Satellite Climatology:

- Retrieval and Validation of Surface and Atmospheric Parameters Using Satellite Measurements
- Changes in Annual Global Precipitation (1979-2004)
- Evaluation of the Aerosol Retrieval Algorithm for NPOESS/VIIRS
- A Fire Identification, Mapping and Monitoring Algorithm for Global Emissions Estimates

Appendix B: Inter-Agency Agreements

Office of the Federal Coordinator for Meteorology Operations Plans:

National Severe Local Storms Operations Plan, May 2001
National Winter Storm Operations Plan, November 2000
National Hurricane Operations Plan, May 2003

Federal Plan for Meteorological Services and Supporting Research, June 2002

Environmental Support Plan for Homeland Security (under development)

The Federal Emergency Management Agency's (FEMA's) Federal Response Plan (FRP), April 1999 that implements the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended (42 U.S.C. 5121, et seq.)

Interagency Cooperation with the U.S. Army Corps of Engineers, U.S. Department of Interior, U.S. Department of Agriculture, U.S. Bureau of Reclamation, and the National Aeronautics and Space Administration. These agreements assign NOAA the responsibility for collecting climate, weather, and snow data and for providing forecasts for river levels, floods and flash-floods. NOAA's Advanced Hydrologic Prediction Service (AHPS) has been approved by Congress since 2000 to improve the Nation's capability to take timely and effective action to save lives and mitigate the economic losses from major floods and droughts.

Appendix C: List of Abbreviations and Acronyms

ABBA	Automated Biomass Burning Algorithm
ABI	Advanced Baseline Imager
ABS	Advanced Baseline Sounder
ACARS	Aircraft Communications and Reporting System
AE	Auto-Estimator
AHPS	Advanced Hydrologic Prediction Service
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
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
ASPB	Advanced Satellite Products Branch
ATOVS	Advanced TIROS Operational Vertical Sounder
AUTEC	Atlantic Undersea Test and Evaluation Center
AVHRR	Advanced Very High Resolution Radiometer
AWIPS	Advanced Weather Interactive Processing System
CCR	Cloud Cleared Radiances
CCRS	Canada Center for Remote Sensing
CCSP	Climate Change Science Program
CDR	Climate Date Record(s)
CEOS	Committed on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System
CH_4	Methane
CICS	Cooperative Institute for Climate Studies
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIORS	Cooperative Institute for Ocean Remote Sensing
CIOSS	Cooperative Institute for Oceanographic Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CLAVR	Clouds from AVHRR
CMDL	Climate Monitoring and Diagnostics Laboratory
CMIS	Conical (Scanning) Microwave Imager/Sounder
CMOD4	C-Band Model Function
CNES	French Space Agency
CO	Carbon monoxide
CO_2	Carbon dioxide
COMET	Cooperative Program for Operational Meteorology
CONUS	Continental United States

CoRP	Cooperative Research Program
COSMIC	Constellation Observing Satellites for Meteorology, Ionosphere, and Climate
CPC	Climate Prediction Center
CPUE	Catch Per Unit Effort
CRAD	Climate Research and Applications Division
CREST	Cooperative Remote Sensing Science and Technology Center
CrIS	Cross-track Infrared Sounder
CRTM	Community Radiative Transfer Model
DAAC	Distributed Active Archives Center
DAO	Data Assimilation Office
DHW	Degree Heating Weeks
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DWL	Doppler Wind Lidar
ECMWF	European Centre for Medium-Range Weather Forecasts
EDC	EROS Data Center
EDR	Environmental Data Record
EMB	Environmental Monitoring Branch
EMC	Electromagnetic Compatibility
EOS	Earth Observation/Observing System/Satellite
EPA	Environmental Protection Agency
ERBS	Earth Radiation Budget System
ERD	Environmental Data Record
EROS	Earth Resources Observation System
ERS	European Remote Sensing
ESA	European Space Agency
ESPC	Environmental Satellite Processing Center
ETL	Environmental Technology Laboratory
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EVP	Environmental Visualization Program
FEMA	Federal Emergency Management Agency
FRP	Federal Response Plan
FTP	File Transfer Protocol
GDAS	Global Data Assimilation System
GDP	Gross Domestic Product
GDR	Geophysical Data Record
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GIMPAP	GOES Improved Measurements and Product Assurance Plan
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
GSIP	GOES Surface and Insolation Project
GVF	Green Vegetative Fraction
GVI	Global Vegetation Index
GVIGVF	Green Vegetation Index
HAB	Harmful algal bloom
HES	Hyperspectral Environmental Suite
HIRS	High-Resolution Infrared Radiation Sounder
IASI	Infrared Atmospheric Sounding Interferometer
IEOS	Integrated Earth Observing System
IFCT	Instrument Functional Chain Team
IFFA	Interactive Flash Flood Analyzer
IGBP	International Geosphere Biosphere Programme
IGEO	Integrated Global Environmental Observation
IGOS	Integrated Global Observing Strategy
IJPS	Initial Joint Polar-orbiting Satellite
IMI	Irish Marine Institute
IOCCG	International Ocean Color Coordinating Group
IOOS	Integrated Ocean Observing System
IPT	Integrated Process Team
IR	Infrared
IT	Information Technology
IVL	International Virtual Laboratory
JPL	Jet Propulsion Laboratory
JCSDA	Joint Center for Satellite Data Assimilation
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
MOCE	Marine Optical Characterization Experiment
MODIS	Moderate Resolution Imaging Spectroradiometer
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center

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
NHC	National Hurricane Center
NIC	National Ice Center
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
NPP	NPOESS Preparatory Project
NRCS	Normalized Radar Cross-Section
NSF	National Science Foundation
NWP	National Weather Prediction
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OC	Ocean Color
OH	Office of Hydrology
OLR	Outgoing Longwave Radiation
OPDB	Operational Products Development Branch
OPT	Ozone Processing Team
ORA	Office of Research and Applications
ORAD	Oceanic Research and Applications Division
OSCAR	Ocean Surface Current Analysis Real-time
OSDAD	Office of Satellite Data Processing
OSDPD	Office of Satellite Data Processing and Distribution
OSSE	Observing System (Simulation) Experiment
OSW	Ocean Surface Winds
P.L.	Public Law
PATMOS	Pathfinder Atmosphere
POES	Polar-orbiting Operational Environmental Satellites
POP	Product Oversight Panel
QPE	Quantitative Precipitation Amounts
QPF	Quantitative Precipitation Forecasts
R&D	Research and Development
RAMMB	Regional Mesoscale Meteorology Branch
RAMMT	Regional and Mesoscale Meteorology Team
RAMSDIS	Regional and Mesoscale Meteorology Team Advanced Meteorological Satellite Demonstration and Interpretation System
RFI	Radio Frequency Interference

RPP	Research Project Plan
SAR	Synthetic Aperture Radar
SBUV/2	Solar Backscatter Ultraviolet Spectral Radiometer, MOD 2
SCSB	Satellite Climate Studies Branch
SECW	Southeast CoastWatch Program
SHIPS	Statistical Hurricane Intensity Prediction Scheme
SHyMet	Satellite Hydro-Meteorology
SI	Sea Ice
SMCD	Satellite Meteorology and Climatology Division
SNO	Simultaneous Nadir Overpass
SOCD	Satellite Oceanography and Climatology Division
SPB	Sensor Physics Branch
SRSO	Super-Rapid Scan Operations
SSH	Sea Surface Height
SSM/I	Special Sensor Microwave Imager
SSR	Sea Surface Roughness
SST	Sea Surface Temperature
STAR	Center for Satellite Applications and Research
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
U.S.C.	United States Code
UKMO	United Kingdom Meteorological Office
USDA	United States Department of Agriculture
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
USWRP	United States Weather Research Program
UV	Ultraviolet
VCI	Vegetation Condition Index
VIIRS	Visible/Infrared Imager/ and Radiometer Suite
VIRS	Visible Infrared Scanner
VISIT	Virtual Institute for Satellite Integration Training
WF_ABBA	Wildfire, Automated Biomass Burning Algorithm
WINDEX	Wind Experiment
WMO	World Meteorological Organization