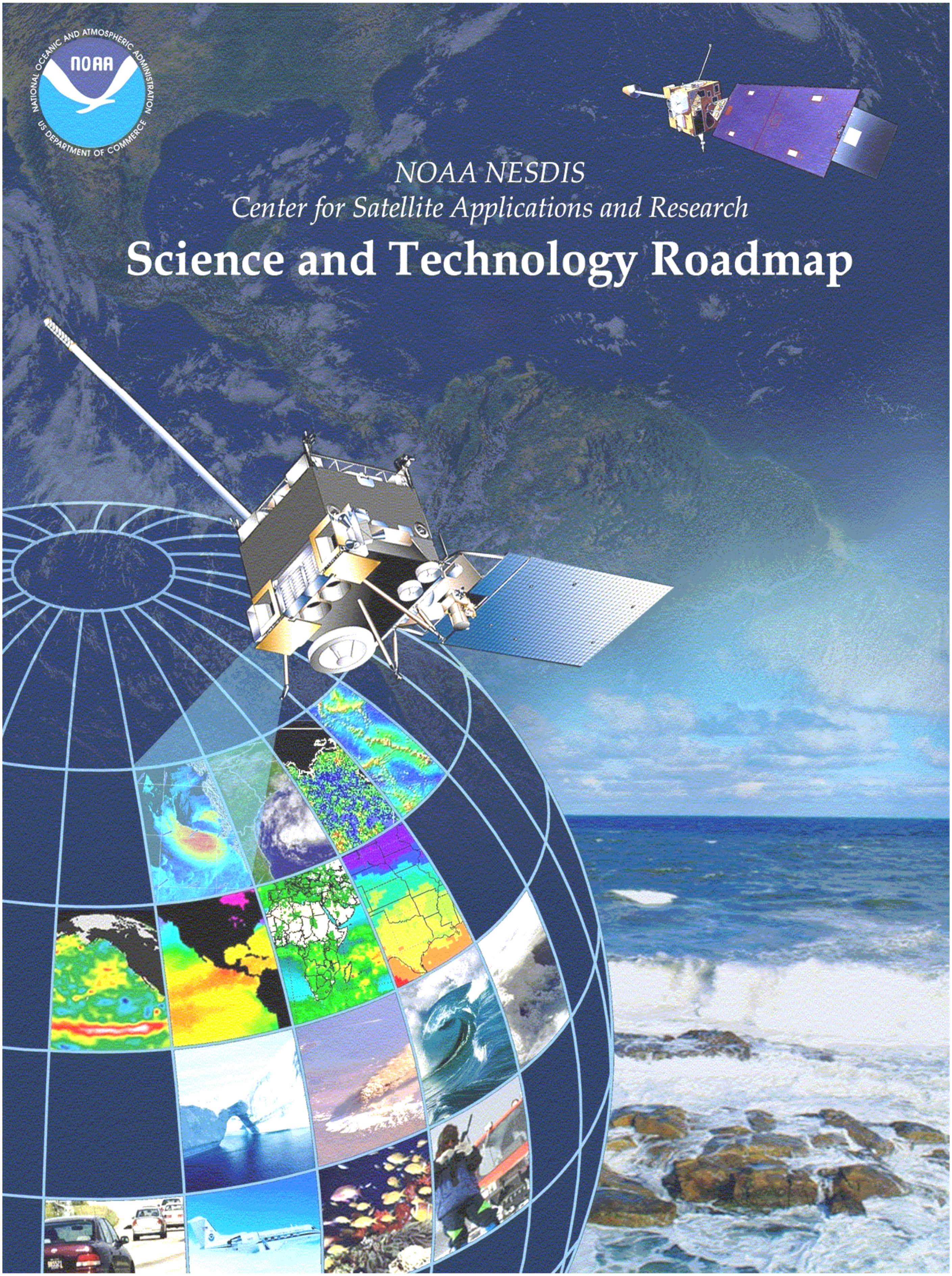
NOAA NESDIS

Center for Satellite Applications and Research

Science and Technology Roadmap



NOAA / NESDIS

*Center for Satellite Applications and Research**

Science and Technology Road Map

*(Formerly Office of Research and Applications)

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Executive Summary

The United States invests billions of dollars annually in environmental satellites in order to 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 on the Earth. This road map outlines how the Center 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) which acquires and manages the nation's Earth-observing satellites, that 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, as well as to offer state-of-the-art satellite data, products and services to decision-makers. STAR leads in the planning of future satellite observing systems to enhance the nation's ability to remotely sense the environment; calibrates the earth observing instruments of all NOAA satellites to provide reliable, accurate measurements; and from those measurements develops data products to:

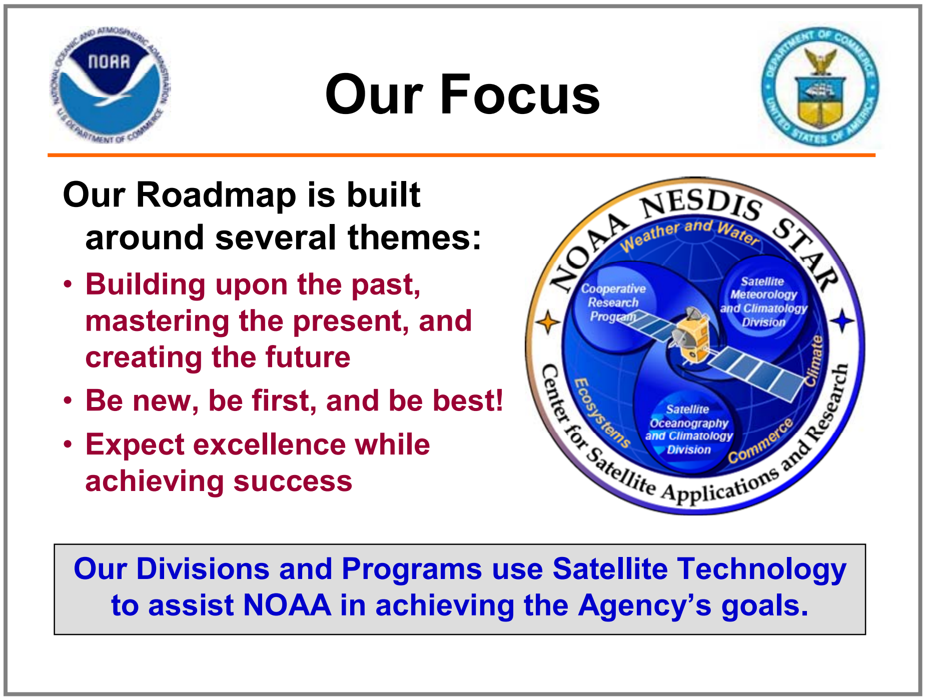
- Assess the current conditions on the Earth in a timely manner,
- Predict changes in the current conditions,
- Study long-term trends in the environment.

STAR's research and development program helps NOAA achieve its 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) provides satellite-based remote sensing of the ocean, by developing products from ocean observations, and transferring results from research into operational practice.



- The Cooperative Research Program (CoRP), through a unique partnership between STAR and universities, engages experts in the academic community to realize the vision of STAR. Each of three branches of CoRP - consisting of government scientists - is collocated with a Cooperative Institute managed by a University.

The Center'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 will monitor, assess, and predict the health of ecosystems in the nation and its regions, using NOAA's global system for observing 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." There are two strategies of NOAA 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 role is to construct research-quality records of climatic variables in the 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** Goals, which are to increase the lead-time and accuracy of weather forecasts and warnings, and of river forecasts, and to improve the prediction of the onset, duration, and impacts of severe weather and river flooding. Also STAR 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 hazards in air transportation (the Aviation Weather program), and marine transportation (the Marine Weather program).

Important trends in instrument technologies to be implemented in the next generation of operational satellites include:

- "*Hyperspectral*" instruments for sounding and imaging the environment of Earth with greater detail than ever possible will measure the atmosphere, land, and oceans with unprecedented information content, frequency, and timeliness.
- Radar, lidar, and radio instruments that will measure the **vertical structure of the atmosphere,** including temperature, moisture, clouds, precipitation, and aerosols.
- Radar instruments that 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 that provide the first space-based information on ocean salinity, soil moisture, and aerosol properties; and establish the role of NOAA in observing ocean color, solar radiation, and the radiation budget of Earth, now observed only by research satellites of other agencies.

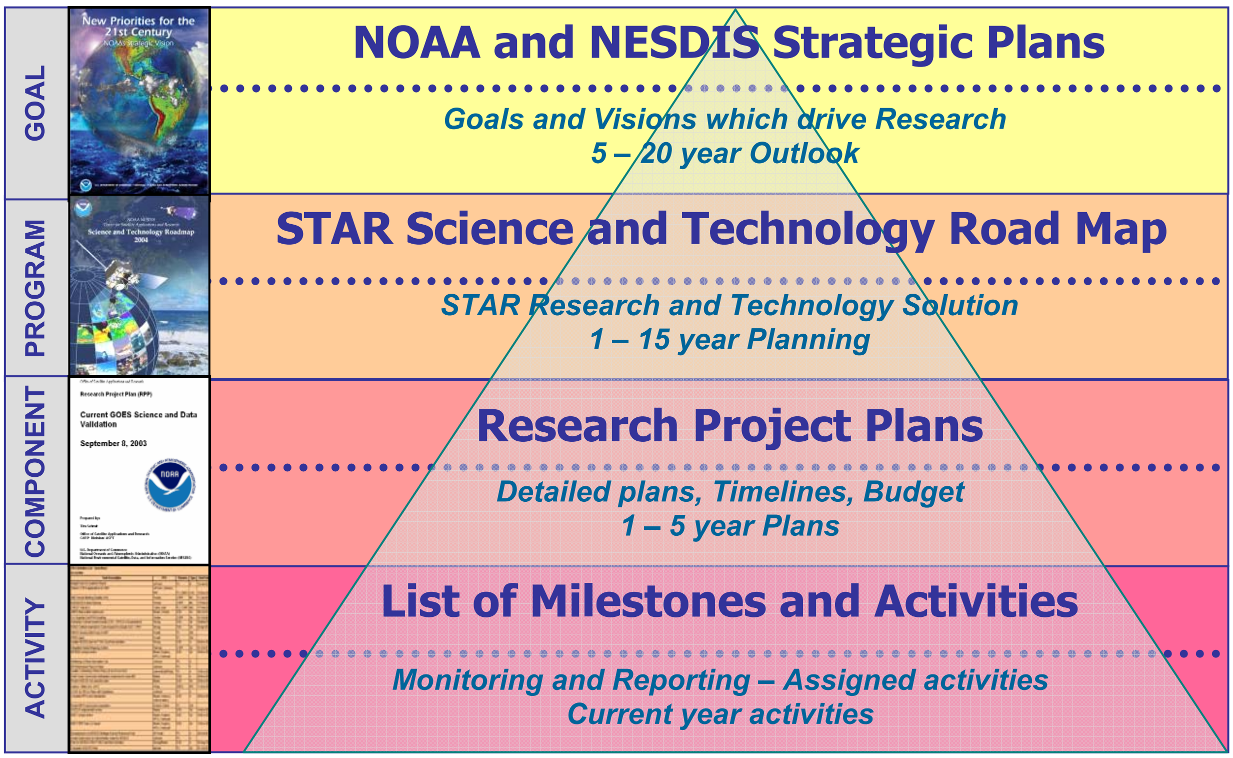
Responding to these user requirements and satellite technologies, STAR has written this *Science and Technology Road Map* for 38 science projects that support NOAA's Strategic Goals. These projects enable the delivery of new satellite observations into computer models that simulate and predict the environment, especially 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.

STAR will create new products for dealing with 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 performance targets will be facilitated by a dramatic increase in observing capabilities over the next five years; by a world-class team of government scientists supported by a competent cadre of contractors 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 on land, sea, and in the air, and anticipated losses of senior scientists as a result of retirement.

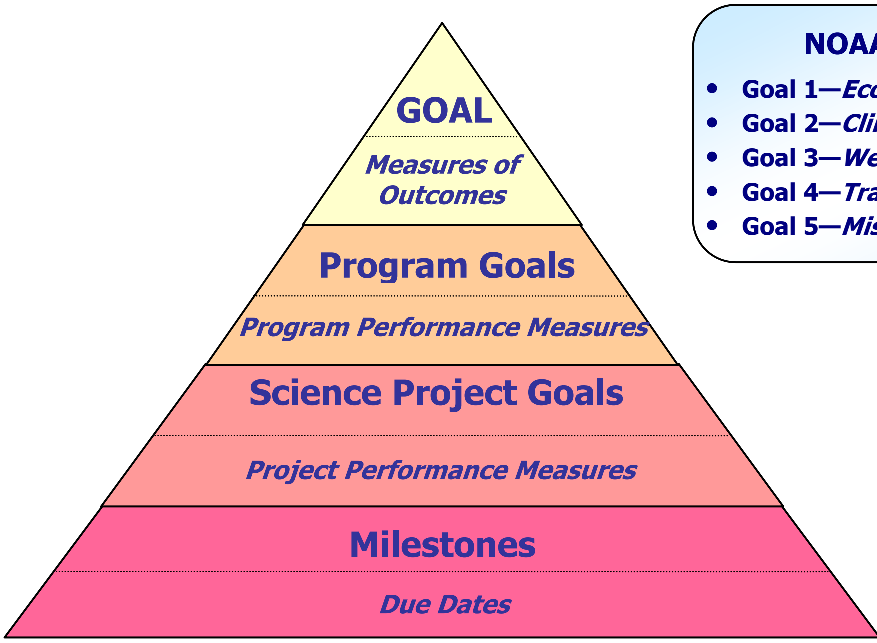
1 Introduction

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 Agency for the next five to twenty years. The Center is located in the National Oceanic and Atmospheric Administration (NOAA), and within that, in the National Environmental Satellite, Data, and Information Service (NESDIS). This Road Map is a necessary step in the planning process, which begins with guidelines in the NOAA Strategic Plan and the Annual Guidance Memorandum. This Road Map guides the writing of the Road Maps of the three Divisions and the Research Project Plans (RPPs). The STAR planning pyramid, modeled after a pyramid that NOAA uses to measure performance, appears in the Figure below.



This Road Map is organized by 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 which support Performance Goals of the Center and describe significant milestones. This STAR Road Map will be updated every three to five years or more often as necessary.

The pyramid below illustrates how the components of the Road Map are related.



NOAA Strategic Goals

- **Goal 1—*Ecosystems***
- **Goal 2—*Climate***
- **Goal 3—*Weather and Water***
- **Goal 4—*Transportation and Commerce***
- **Goal 5—*Mission Support***

In addition to mapping STAR activities to the NOAA Strategic Plan, this Road Map also:

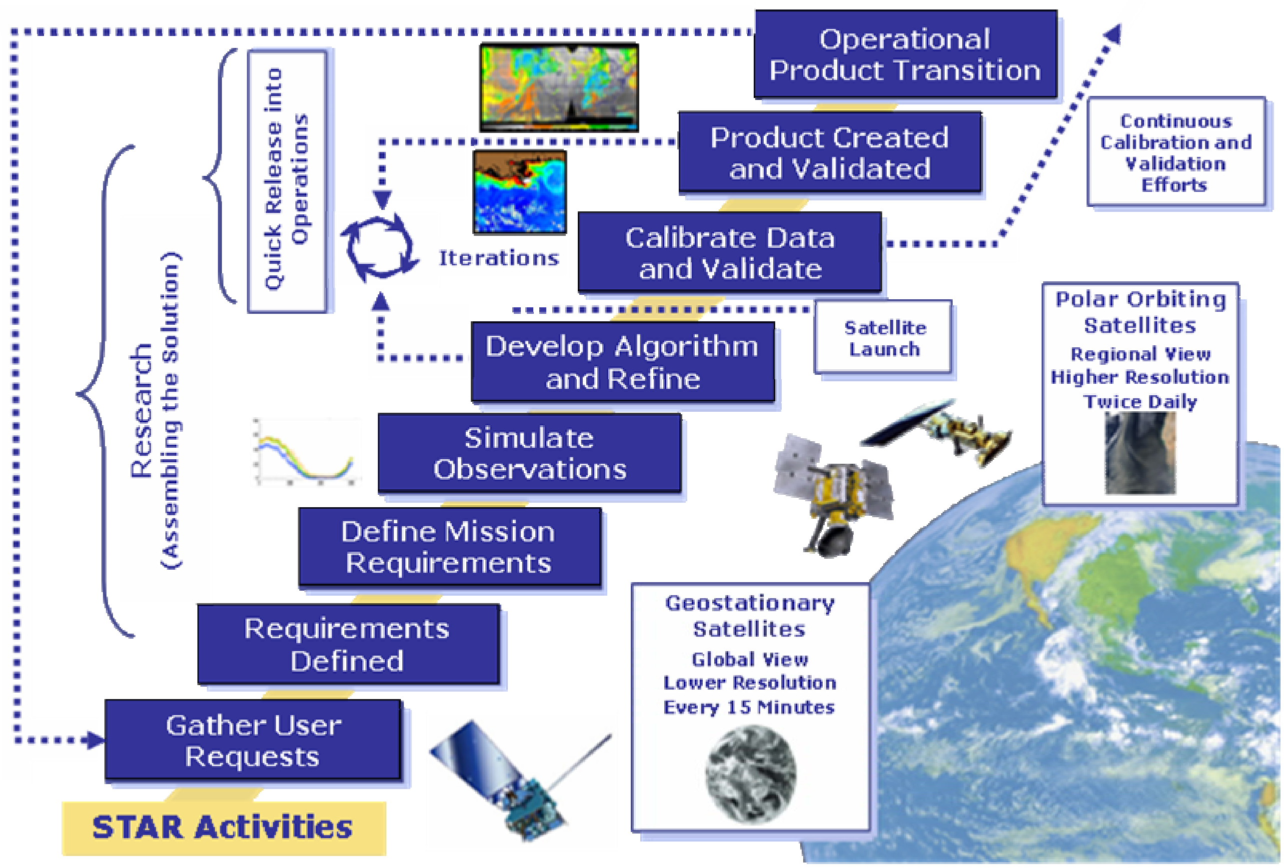
- Informs stakeholders how STAR will address their requirements
- Shows relationships among research activities
- Identifies key technologies and skills in which STAR has a competitive advantage

Using this Road Map, STAR will be able to:

- Predict future technologies that STAR will use to make or improve scientific products
- Locate gaps in research, technology, and plans for innovation
- Ascertain the best and most realistic set of targets
- Negotiate options for spending or investment by the Center
- Network team members in this Center with other programs in NOAA and other agencies
- Identify the best solutions to fulfill demands of users of STAR products, instead of being restricted to the possibilities allowed by existing applications
- Note the alternatives, allowing the STAR team to recognize and act on events that require a change in direction — *planning for the unexpected*
- Inform users of new or enhanced products, so they can plan their activities—end-to-end planning

2 Background

The Center for Satellite Applications and Research (STAR) is an operations-driven research and development center in the US government, tuned to the needs of the Nation's users of satellite data products. STAR supports diverse research within the remote sensing arena, including study of atmospheric, oceanic, and land processes. STAR participates in NOAA satellite activities from beginning to end: from defining the initial requirements for a satellite and its mission, through calibration and then use of the associated data, to final archival and even reprocessing of that data, for all operational NOAA satellites. See the Figure below.



STAR supports the NOAA mission in all the stages of data use indicated above. NOAA maintains operational satellites and produces data and products from those 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. Without intervention by this Center in processing satellite data, operational products using such data would not be as accurate or reliable, and EVERY user would be required to perform time consuming and complicated adjustments prior to using the information. STAR provides significant value to the community of satellite users via its calibration and validation role alone. It allows every user to derive immediate benefit from satellite data, whether raw data or products, by accomplishing this quality control cost-effectively in a single office prior to distribution. Decisions based on STAR products are thus much more sound.

To assure continuity, NOAA continually plans for new satellites to replace old satellites and to utilize 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.

STAR investigates how to develop satellite data sets which can be used to:

- Assess the current conditions on the Earth in a timely manner,
- Predict changes in the current conditions,
- Study long-term trends in the environment.

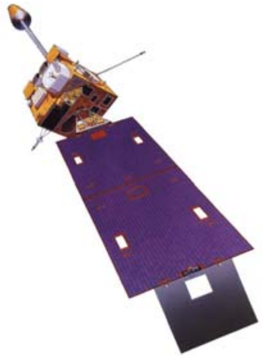
The data sets developed by STAR are used by scientists worldwide for the study of the earth and its environment.

STAR develops products which the operational community of users (including academic, commercial and government users) can interpret and analyze. This information helps the public and private sectors make more informed choices that benefit their lives and businesses.

2.1 Vision and Mission of STAR

STAR Vision

To advance satellite science and technology to better inform and safeguard the American public.



STAR Mission

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

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.html.

2.2 STAR Values

Professional government, contractor, and university staffs 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 on 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 follow-on Development (R & D) according to these principles:

Create: Be New. Generate fundamentally different ideas, instruments, techniques, or prototypes. The work is complex but its scope is usually small. 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 capabilities. The work is complex and the scope can range from small to large. This leads to **products.**

Improve: Be Better. Incrementally improve or standardize an existing model, technique, product, process, or technology. The work is not very complex and its scope can range from small to large. This leads to **enhancements.**

Master: Be Sustainable. Generate incremental advances in knowledge, to master, extend, or share existing ideas, techniques, or technologies. The work is not very complex and its scope can range from small to large. This leads to **mastery.**

3 Trends and Drivers

STAR's strategy for improving remote-sensing systems and their use is to: (1) contribute to the decisions that NESDIS makes about systems, programs, and applications, (2) leverage more resources by maintaining and enhancing outside collaborations, (3) foster strong working relationships with the entire user community both locally and globally, and (4) 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 scientific services to the users of NOAA's satellites. STAR provides the following services:

- Plans new satellites and sensors that monitor the environment;
- Collects, processes, archives and distributes data from environmental satellites;
- Builds quality and reliability into NOAA satellite data, products and services;
- Provides satellite products & services which NOAA and others can use to accomplish their mission.

NOAA's mission includes public service affecting the earth's atmosphere, land, and ocean. Those services 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 the agency to deliver these public services.

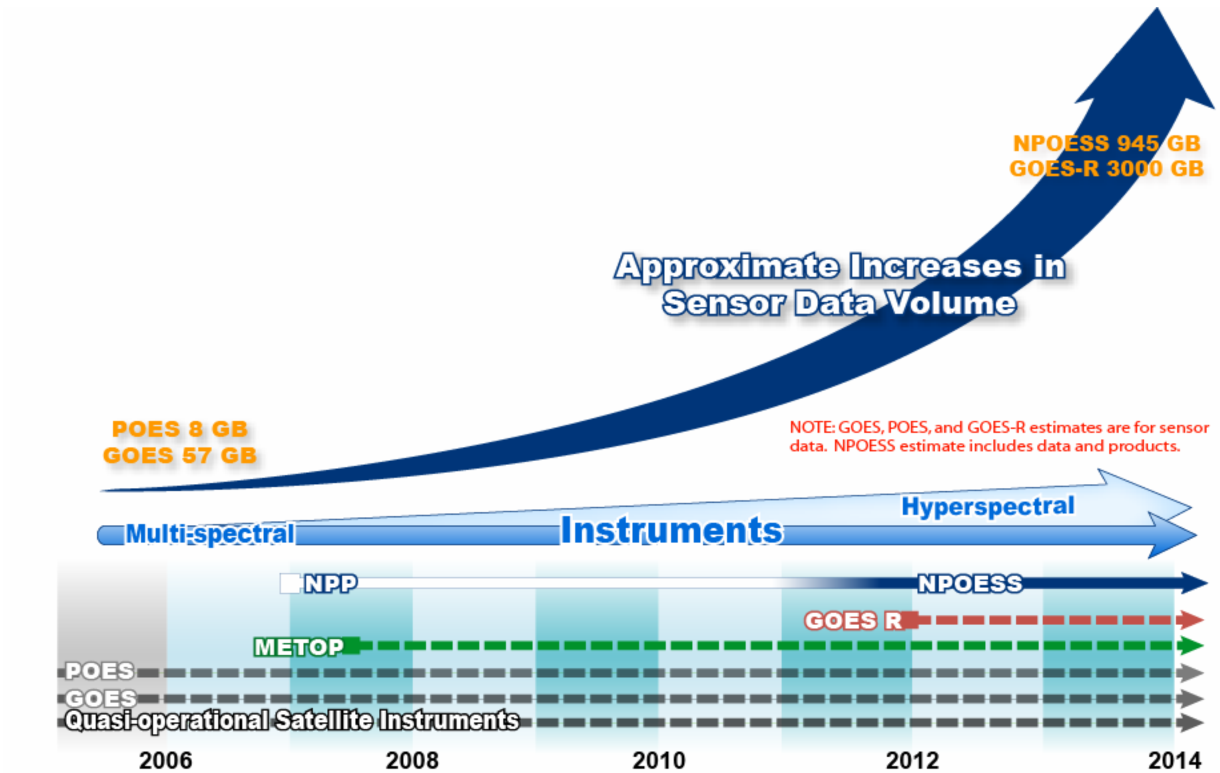
Since NOAA collaborates with other scientific organizations all over the world, STAR supports scientific collaboration in the area of satellite information and use. STAR shares its research and data with other government offices and with international scientific partners.

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 construct an integrated global system of environmental observation data, which will require integration with the 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 possible: its scientists already have developed new products that NESDIS will provide to operational users. STAR ensures that the data derived from the next–generation polar orbiting satellites (NPOESS) and future geostationary satellites (GOES-R) will provide the best value possible to the users for this Nation's investment. The calibration and validation teams lead the way in enabling the best information to be provided from the entire network of satellites.

As each new mission becomes operational, the world class scientists in STAR continue to develop new practical applications from cutting edge research in order to meet or exceed the requirements of users Once the satellites are operational, the improved monitoring and forecasting of the environment will allow better decisions to be made, at lower cost. (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 there is a need to build a comprehensive and integrated system of 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 quickly to more users. That means that STAR must be creative in support of these demands on NESDIS.

Remote sensing of the environment has undergone rapid change in the last decade, as the number of sensors and telecommunications channels has exploded. 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 are predicting that the volume of data will grow by ten orders of magnitude in the next ten years!

		Today	2008-2016	2020+
Satellites	*Polar*	3	3	3
	Geostationary	2	2	2
	Non-NOAA	5	12	14
Sensors		30	45	70
Spatial Resolution		1-8 km	1-4 km	200 m-1km
Temporal Resolution		90 min/30 min	90 min/30 min	90 min/5 min

As noted above, 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 US to fully exploit this new information. During the 1990s, the capability of communications and computing also increased dramatically, which made it possible for STAR to partner with international scientists who are improving the monitoring and use of such data.

3.3 Collaboration with Resources

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 more and better 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 as 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 "*METOP*," the new European satellite, which will serve the entire globe by providing data to the National Polar-orbiting Operational Environmental Satellite System. 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. Challenges to be addressed include the following:

- 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 (POES) and geostationary (GOES) satellite systems will be very different than it is 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: "*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 leads international programs to further understanding of the earth's environment and to develop 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.

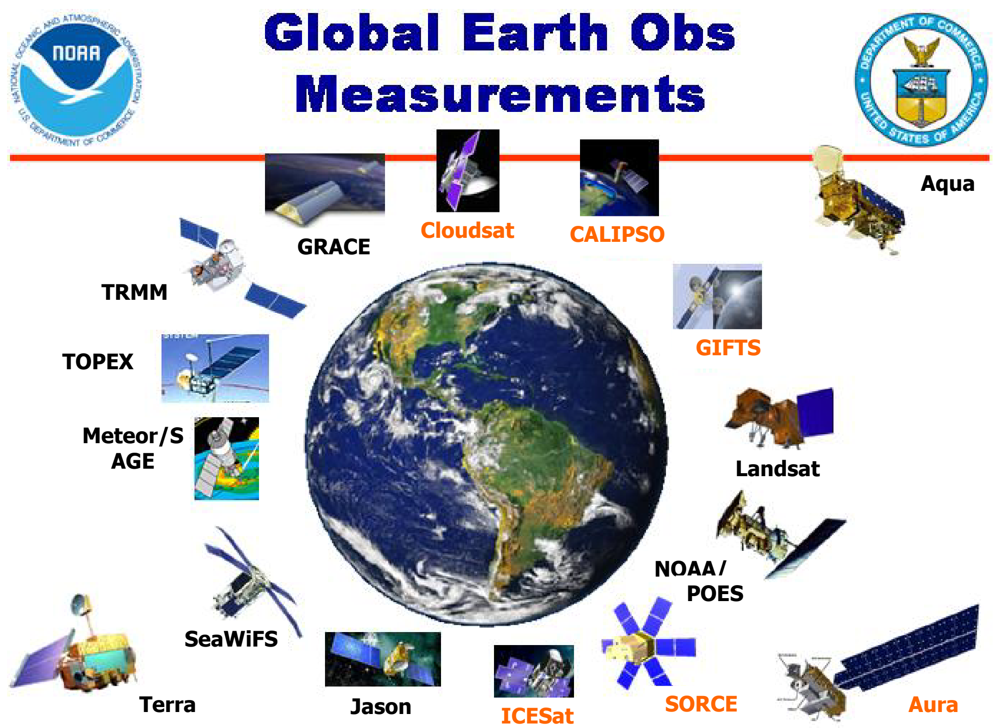
STAR leads the effort to expand national and international remote sensing capabilities. There are several examples in which STAR scientists either serve as chair or participate as members. STAR both participates in and advises the teams that are planning the next generation of polar orbiting satellites, along with partners in the National Aeronautics and Space Administration (NASA) and the Department of Defense. STAR 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. Specifically, they serve on two expert teams studying the "Evolution of the Global Observing System" and "Satellite Data Utilization" within the Open Program Area Group on the Integrated Observing Systems. Finally, as NESDIS is a leader on the Committee on Earth Observation Satellites (CEOS), STAR helps to coordinate programs of Earth observation on the international scale.

STAR fosters international partnerships with organizations all over the world having a focus on satellite data. Examples include the European Space Agency and EUMETSAT, and space agencies and science organizations in India, Japan, China, Russia, and Korea.

NOAA's leadership in the "Global Earth Observation System of Systems" (GEOSS) is in the nation's interest but 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 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
- 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.



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 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 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 responsibilities in warning and forecasting. 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.

3.6 NOAA's Strategic Plan

NOAA developed its Strategic Plan to explain how NOAA 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 the five NOAA 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" which provides the "big picture" of where NOAA will go and the role that research will play. The NOAA Administrator also distributes his Annual Guidance Memorandum that relays his priorities to his organization for the year. At the annual meeting of the American Meteorological Society in January 2005, the NOAA Deputy Under Secretary stressed the following areas as NOAA priorities:

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

3.7 The Mandate

The strategy of the Center for Satellite Applications and Research (STAR) is given in Publication L 10: "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 both 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), especially Section 515, which provides a legal basis for NOAA research. However there are several more mandates for specific areas of STAR's mission:

Ecosystems:

- *National Environmental Policy Act of 1971* (42 USC 4321 et seq.) set up environmental impact statements, including investigations of protected species.
- *Marine Mammal Protection Act of* 1973 (U.S.C. 1361-1407) also set up protected species.
- *Endangered Species Act of 1973* (U.S.C. 1653-1543) set up procedures to declare species as protected.
- *Marine Protection, Research and Sanctuaries Act* (PL 104-283**)** set up 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 U.S.C. 1121 et seq.) mandated monitoring of algae and response to bloom events.

Climate:

- The *Global Change Research Act of 1990* (P.L. 101-606, 15 U.S.C. 2921 et. seq.) set up the U.S. Global Change Research Program, managed by NOAA, which evolved into the Climate Change Science Program thirteen years later.
- *Clean Air Act Amendments of 1990* (Public Law 95-95) requires NOAA and NASA 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 (and NASA) are required to report "…the current average tropospheric concentration of chlorine and bromine and the level of stratospheric **ozone depletion**."
- The US *Climate Change Science Program* (CCSP) was set up by Executive action in 2002, as a merger of the US Global Change Research Program (see item #1 above) with several new programs. Furthermore, it brought together 13 distinct Federal agencies.
- *U.S. Carbon Cycle Science Plan (USGCRP, 1999)* and associated implementation plans. This plan defined five goals, of which three pertain directly to NOAA expertise: "Quantify and understand the Northern Hemisphere terrestrial carbon sink", "Quantify and understand the uptake of anthropogenic CO_2 in the ocean", and "Provide greatly improved projections of future atmospheric concentrations of CO_2." NOAA's Climate Forcing Program is designed to meet those goals.

***Weather and Water*:**

- *The Organic Act of October 1, 1890*, which created the National Weather Bureau, established NOAA's mission to provide weather and water information to the Nation.
- The *Inland Flood Forecasting and Warning System Act of 2002*, U. S. Code Title 15, Chapter 9 (Public Law 107-253), set up a system for monitoring rainfall and warning of river flooding.

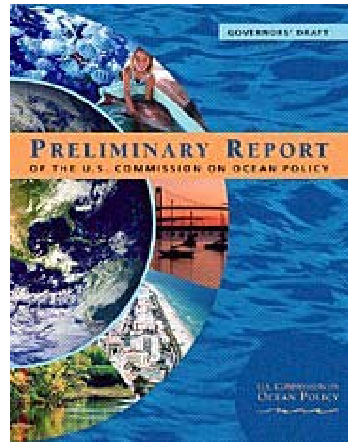
- *U.S. Code Title 15, Chapter 9, Section 313:* "The Secretary of Commerce shall have charge of the **forecasting of weather, the issue of storm warnings,**…for the benefit of agriculture, commerce, and navigation,…and the collection and transmission of marine intelligence for the benefit of commerce 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."
- The *Robert T. Stafford Disaster Relief and Emergency Assistance Act,* as amended (Public Law 106-390), U.S. Code Title 42, Chapter 68 set up a "Federal Response Plan" (FRP) of the Federal Emergency Management Agency (FEMA), in 1999. The FRP plan tasks the Department of Commerce (DOC) 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 (*Public Law 87-843) (1963), 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:* The U.S. Weather Research Program (USWRP) is mandated to 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 and appropriations in later years*: H.R. 4 (with Senate Amendment, S. 517), Part II, Section 1383: NOAA shall issue air quality forecasts and perform regional air quality assessments.
- *The 1990 Clean Air Act Amendments, "Great Waters"* Section (Section 112(m), Title III) *Atmospheric Deposition to Great Lakes and Coastal Waters*: NOAA shall identify and assess the extent of deposition of atmospheric pollutants to significant water bodies.
- *The 1990 Clean Air Act Amendments, "Ecosystem Research" Section* (Section 901(e), Title IX): NOAA shall 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) signed by the Deputy Secretary of Commerce and the Administrator of EPA, May 2003: NOAA and EPA will collaborate on air quality research, and on forecasting of air quality. NOAA deliverables include improved air quality forecast models and forecast guidance. EPA deliverables include inventory of emissions and monitoring of air quality.

Oceans and Coasts:

- U. S. Code Title 33, Chapter 17, Section 883j, **and "Ocean Satellite Data":** The Administrator of the National Oceanic and Atmospheric Administration…shall take such actions, including the sponsorship of applied research, as may be necessary to assure 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. It created the U.S. Commission on Ocean Policy, which published ***An Ocean Blueprint for the 21st Century.*** The Commission's findings and recommendations resulted in the President's U.S. Ocean Action Plan. The Commission report and the Plan spell out many research activities of the Satellite Oceanography Division.
- *National Marine Sanctuaries Act* (PL 106-513; U.S. Code, Title 16—Conservation, Chapter 32--Marine Sanctuaries, Sec. 1431) set up the Sustainable Seas Experiment.

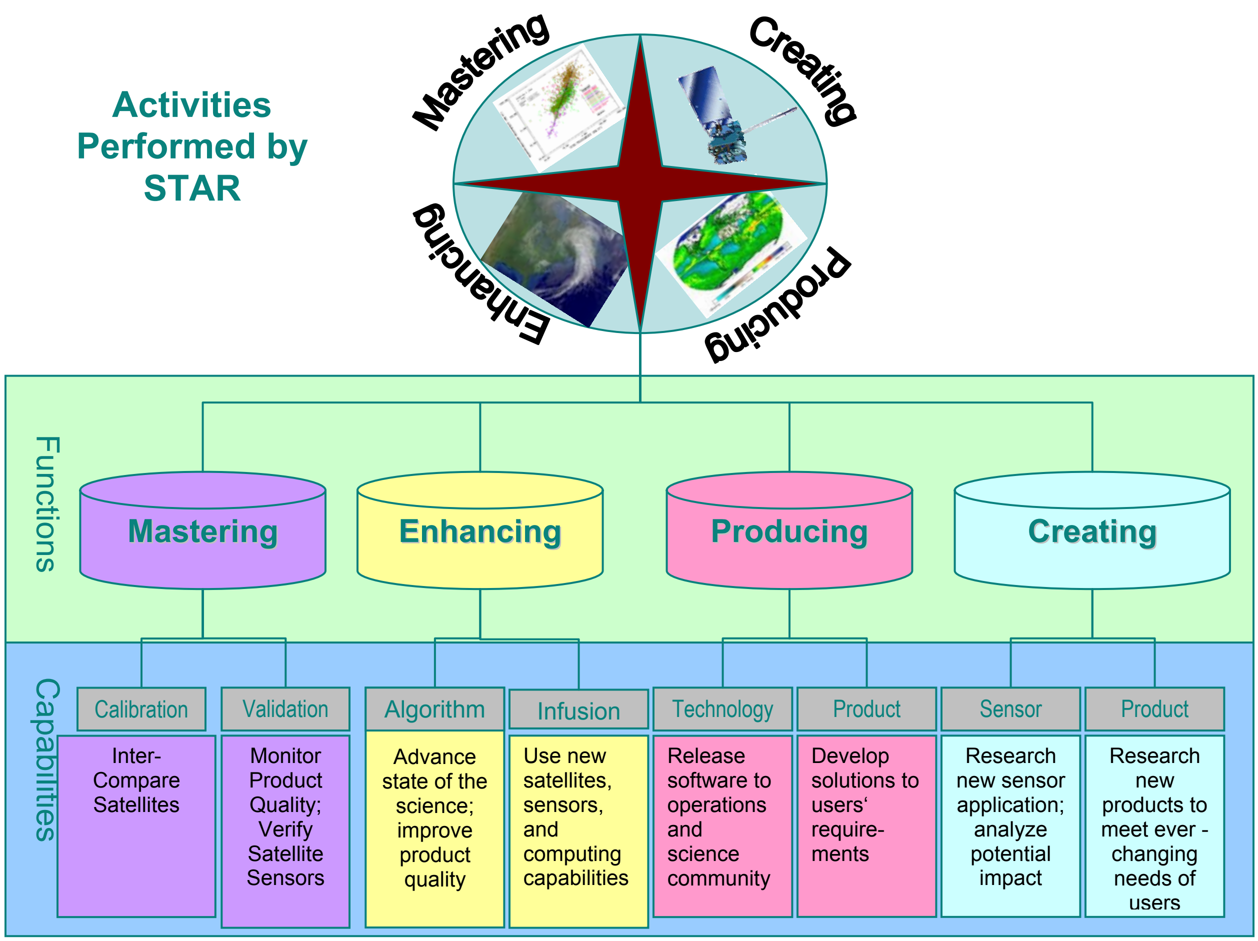
Transportation and Commerce:

- *U.S. Code* Title 49—**Transportation**, Subtitle vii--Aviation Programs, Part A--Air Commerce And Safety, Subpart iii—Safety, Chapter 447--Safety Regulation, Sec. 44720 set up 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 *Concept* stage of system and product development, STAR works with the users to identify their requirements and the important science questions. STAR scientists then do research on new sensor technology, products and applications to meet the requirements. In the *Production* 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, customers send feedback on it that guides the choice of areas for *Enhancement*. Refining the formulas used to produce operational products, and combining data from other sensors are some techniques used to improve the products. In the *Mastery* phase, STAR shares the science with others to promote creative thinking about methods to use satellite data to obtain better information about the globe and its environment. Finally, quality and excellence are built into routine methods for processing data.



STAR is divided into three Divisions to optimize its efforts: 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) of STAR 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. It monitors many different atmospheric hazards, and finally, SMCD calibrates and validates satellite data for the highest quality climate records.

Satellite Meteorology and Climatology Division

The results of this Division's research have potentially 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, so this

Division's research is important to the Nation's economy. SMCD applications assist weather prediction modelers and forecasters in the forecasting of aviation hazards, floods, hurricanes, and severe weather, all of which keep the population safe.

To manage its projects better SMCD is divided into three branches:

4.1.1 The Environmental Monitoring Branch (EMB)

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

4.1.2 The Operational Products Development Branch (OPDB)

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. It investigates phenomena that affect the nation's aviation industry, including fog, icing, and turbulence. It studies how best to monitor harmful ultraviolet rays from the sun, to help inform and protect the public while outdoors.

4.1.3 The Sensor Physics Branch (SPB)

The Sensor Physics Branch is investigating 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, a job this Branch takes very seriously.

4.2 The Satellite Oceanography and Climatology Division

There is little appreciation of the fact that more than 70% 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.

Satellite Oceanography and Climatology Division

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. For example, 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 nine million barrels of oil daily aboard ships, and dependent on their safe travel. The Division also responds to the need for stewardship of marine ecosystems, by monitoring global bleaching of coral reefs, and supporting the protection of endangered species.

The Division is organized into three branches:

4.2.1 The Satellite Ocean Sensors Branch

The Satellite Ocean Sensors Branch investigates how to apply remote sensing technology to the need of oceanography. Their task is to develop 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 sea, surface winds over the ocean, and various uses of information on ocean color in physics and biology. Other research includes developing optical instruments for use in the water or on buoys, and using microwave measurements on aircraft and satellites to determine surface wind speed and direction. An important focus of the branch is to define the physics of the relationships between what a sensor measures and what the end product represents.

4.2.2 The Marine Ecosystem and Climate Branch

The Marine Ecosystems and Climate Branch analyzes satellite data for information on ocean color, sea surface temperature, and surface winds, in order to determine properties of marine ecosystems that are important for monitoring habitats, protecting species, maintaining human health, and promoting sustainable development It also monitors these ocean conditions for an understanding of global climate change. The Branch does research in areas from ice-laden polar seas to coral reefs in the tropics.

4.2.3 The Ocean Dynamics and Data Assimilation Branch

The Ocean Dynamics and Data Assimilation Branch combines data from radar altimeters on board satellites with on-site observations in the ocean, in order to determine aspects of the ocean circulation and its variability, to map the marine gravity field and the topography of the ocean bottom, and to use such analyses in simulations of the oceans and atmosphere. Such model simulations are used in prediction of ocean properties and of the weather, and in understanding climate change.

4.3 The Cooperative Research Program

In order to more fully realize the benefits to society of increased exploitation of data from NOAA satellites, the Center for Satellite Applications and Research has teamed with academic partners at four Cooperative Institutes and one Cooperative Center from coast to coast. Each of the 3 branches of the STAR **Cooperative Research Program** (CoRP), consisting of federal government scientists, is co-located with a Cooperative Institute managed by a University. Through such partnerships, CoRP conducts innovative research with current and future professionals in remote sensing.

STAR's Cooperative Research Program

The three federal branches of the Cooperative Research Program, and their associated Cooperative Institutes, are as follows:

4.3.1 The Regional and Mesoscale Meteorology Branch (RAMMB)

The Regional and Mesoscale Meteorology Branch is collocated with the Cooperative Institute for Research in the Atmosphere (CIRA) of Colorado State University, in Fort Collins, Colorado. RAMMB 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)

The *Advanced Satellite Products Branch* is collocated with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) of the University of Wisconsin-Madison in Madison, Wisconsin. ASPB 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)

The *Satellite Climate Studies Branch* is collocated with the Cooperative Institute for Climate Studies (CICS) at the University of Maryland in College Park, Maryland. SCSB 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

There are five Cooperative Institutes or Centers:

- **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; with 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

Table 1. STAR Support for NOAA Goals and Programs

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 & Water	**Local Forecasts and Warnings**	X
	Coasts, Estuaries, and Oceans	X
	Hydrology	X
	Air Quality	X
	Environmental Modeling	X
	Weather Water Science, Technology, and Infusion Program	X
	Space Weather	
	Tsunami	
Commerce & Transportation	**Aviation Weather**	X
	Marine Weather	X
	Marine Transportation Systems	X
	NOAA Emergency Response	
Provide Critical Support for NOAA's Mission	***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	
Matrix Program = blue		

This section maps science activities of STAR for the next five years to NOAA Strategic Goals and to performance goals.

The planning process begins with the NOAA Strategic Plan and the once-yearly Annual Guidance Memorandum from the NOAA Administrator. Using this guidance, 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 the Center to the requirements of users. For each science project, the Research Project Plans (RPPs) specifically describe the work to be performed in the next five years, the milestones to be achieved, financial requirements to be met, and the personnel to be assigned.

The NOAA Goals and Programs supported by STAR are indicated with an "X" at right. NOAA "Matrix" programs are shaded in blue.

STAR's activities and performance goals which 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 observe these critical resources without causing harm, by sensing them remotely from satellites, though our method does have limitations. Clouds and the atmosphere itself often obscure the coastal and oceanic scenes one is trying to see, and the images may not be as detailed as one would like, as the satellites are hundreds of miles above the water. Yet NOAA has successfully observed coastal resources with satellites for many years.

Our Office will have the capability to see 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 are a natural source of data needed to track these rapid and fluctuating changes in water temperature. Such monitoring contributes directly to three NOAA goals: Weather and Water, Ecosystems, and Climate. It also contributes secondarily to another NOAA goal in environmental prediction, which is to predict and assess decadal to centennial change.

5.1.1 Products

Sea Surface Height

The "sea surface height" science team[1] provides global, high-quality altimeter data on "sea level" that helps to understand the rate that sea level is rising, to analyze ocean currents, and to chart the bottom of the ocean better. These science activities help to meet the three NOAA goals of climate variability, ecosystems, and safe & efficient transportation, respectively.

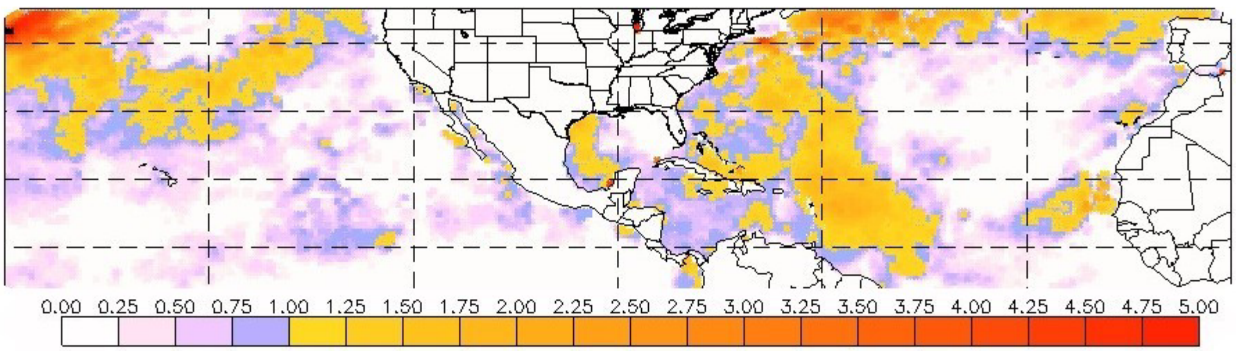
Coral Reef Watch and Sea Surface Temperature

STAR delivers sea surface temperature (SST) data both to 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. 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 Coral Reef Watch just released a new satellite warning product for monitoring coral reef health. The Satellite Bleaching Alert system 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. One HotSpot product is depicted in the figure below, the departure of sea surface temperature from normal (only positive departures are shown). The Satellite Bleaching Alert was developed as a tool for coral reef

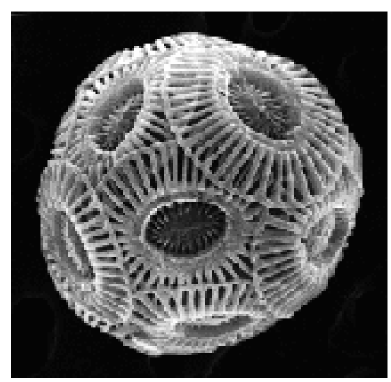
[1] This team bears the name *"Laboratory for Satellite Altimetry."*

managers and scientists by members of the Coral Reef Watch, consisting of STAR and the NESDIS Office of Satellite Data Processing & Distribution. Alert messages are available for 24 coral reefs around the world, at http://coralreefwatch.noaa.gov/ .

Satellite Monitoring of Coral Bleaching to Improve Survival Rates



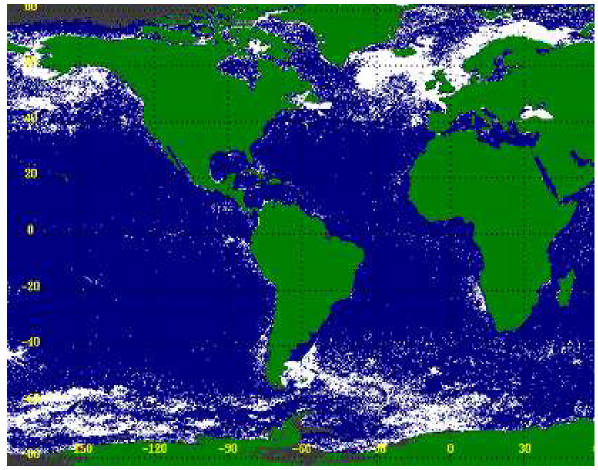
Oceanic Phytoplankton



One of our projects will describe the seasonal and year-to-year variability of phytoplankton, both their biomass and primary productivity, in the world's oceans. Oceanographers hope to locate the phytoplankton and describe their variation over the short and long term. The results will serve as a tool to monitor and assess ecosystem and climate change. For example, STAR scientists are documenting the changing distribution pattern in the ocean of the phytoplankton having the scientific name *Emiliania huxleyi,* using visible satellite imagery. (A microscopic photo of this species is at right.) High concentrations or "blooms" of this phytoplankton species profoundly affect the chemical and optical properties of the waters in which they grow. They may act as a regional source or sink of carbon, depending on various factors. Because they are distributed in upper levels of the subpolar oceans, they may serve as a "sentinel" species for detecting climate change. For this purpose, their distribution in the oceans and the changes in time should be mapped from space, as in this map. Such mapping can be used to evaluate whether this plankton species may be used as an indicator of climate change.

Predicting Marine Organisms

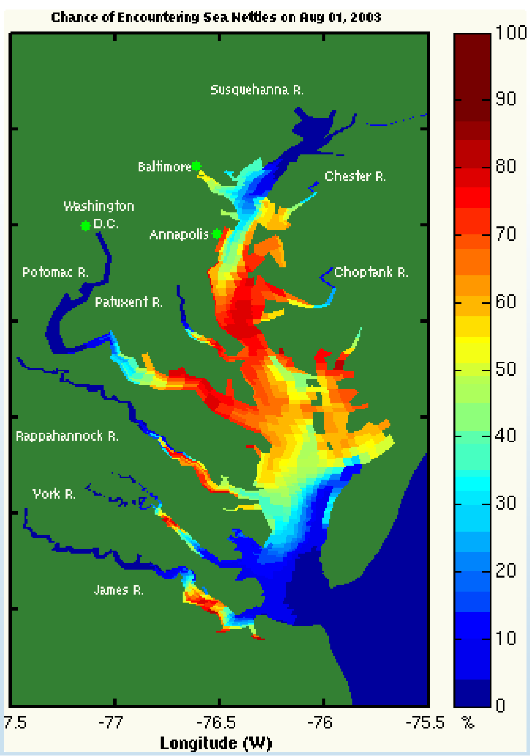
STAR scientists use satellite, model, and *in-situ* data to predict marine organisms that are important to society. Our goal is to develop the ability to detect, monitor and predict the location of marine organisms important to society in coastal and global waters. Towards this goal, STAR is part of 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.



Abundance (in white) of the phytoplankton species Emiliania huxleyi in SeaWiFS satellite imagery.

Locating Sea Nettles

Sea nettles (below, right) seasonally infest the Chesapeake Bay, affecting commerce and recreational activities. Maps (below, left) are created from satellite and field observations; these maps are updated weekly to indicate where environmental conditions are favorable to sea nettles. Recreational boaters and swimmers use these maps to determine areas of probable safe water.



"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."

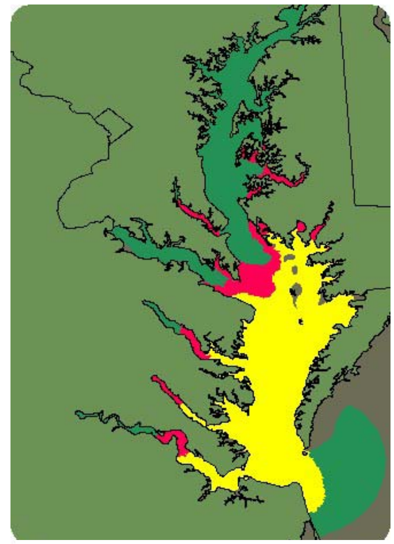
Vaughn Volungis, Denton, MD

Sea Nettles – Predicting a Biotic Nuisance

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 the 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.

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 US. With sufficient warning, coastal resource managers and local authorities have more time to mitigate the harmful effects of HABs. STAR develops products that help to monitor the blooms. Like the sea nettles project, the procedure locates regions where environmental conditions are favorable for the development of these blooms, and exploits the ability to monitor salinity and temperature using satellite data and models. 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 (co-sponsored by STAR) at NOAA Coast Watch Collaborative Projects .



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

STAR also assists the National Ocean Service of NOAA to locate algal blooms in the Gulf of Mexico, and inform 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.

Ocean Color

The Ocean Color science team works to get the most 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 delivers high quality and consistent data on ocean color for marine scientists, coastal resource managers, public health officials and the public. The data assist in maintaining marine ecosystems, supporting sustainable fisheries, and monitoring trends and variability in climate. Ocean color products directly support the NOAA goals of understanding climate change and variability, and stewardship of ecosystems in the oceans.

NOAA CoastWatch becomes global OceanWatch

Over the next several years, the NOAA CoastWatch Program will be wrapped into the OceanWatch Program. Simply put, this involves transferring the 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, 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, science 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 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 whether it results from decade-to-decade variability. The Sea Level Rise project attempts to ascertain the rate of sea level rise and its causes, using all data associated with satellite altimeters.

The STAR science team has primary responsibility for producing, distributing, and archiving the research quality data set for the "Geosat Follow-On" satellite altimeter mission of the US 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 be responsible for the instrument and the operational data, along with the Navy and European space agency partners.

Ocean Currents and El Niño

STAR also monitors currents at the ocean surface with satellite data. The program called OSCAR (for "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 sources, 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 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 under “Ecosystems” above.

Global Precipitation

STAR participates in the Global Precipitation Climatology Project (GPCP) by 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. Most importantly, these products may be useful for investigating the global water cycle. STAR will also develop new schemes for merging data from all available microwave sensors on the polar orbiting satellites.

Monitoring Greenhouse Gases from Space

The amount of carbon released into the atmosphere by industrial sources is reasonably well known. So is the steadily increasing mean concentration of atmospheric 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 the Atmospheric Infrared Sounder (AIRS) instrument of NASA, scientists in the SMC division can now determine the concentrations of three important trace gases in the atmosphere -- carbon dioxide (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, SMCD investigators have shown that CO is a robust and useful product from the AIRS sounder. Carbon monoxide 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 advanced infrared sounders 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

While STAR develops a reliable product for monitoring ozone (Section 4.2.1) for the NWS, which issues a forecast of ultraviolet radiation, the climate science community is happy to use this product for investigating how ozone and other heat-trapping gases affect the climate.

Sea Ice

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

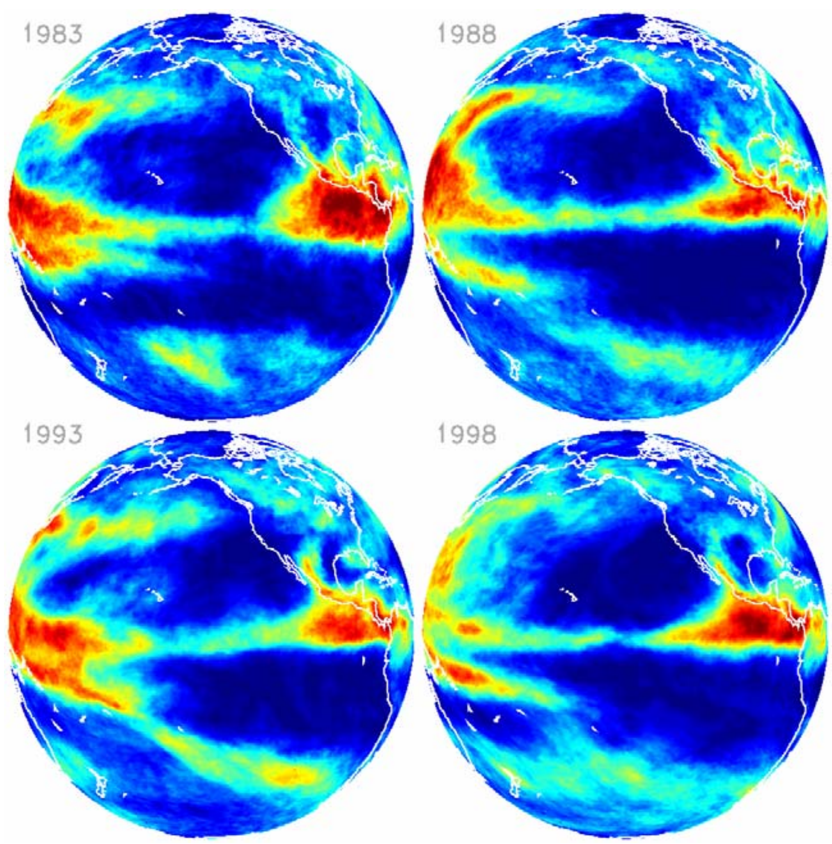
Fires and Aerosols

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 operational satellites. Having obtained the full set of satellite images from 1980 to 2005, this project is applying a lesson learned over the last 25 years -- that one must improve the quality of the image data and products, when reprocessing them for climate studies. For example, the team had to improve the calibration and location accuracy of the historical imager data. Scientists are producing a new and more detailed data set for global vegetation index, for a climatology of polar winds and for a new climatology of sea surface temperature. They are also generating a new complete suite of atmospheric climate products from the imager, including clouds, aerosols, and other properties of the atmosphere. Some results on variability of high cloud amount over the 25-year period are shown on the next page.

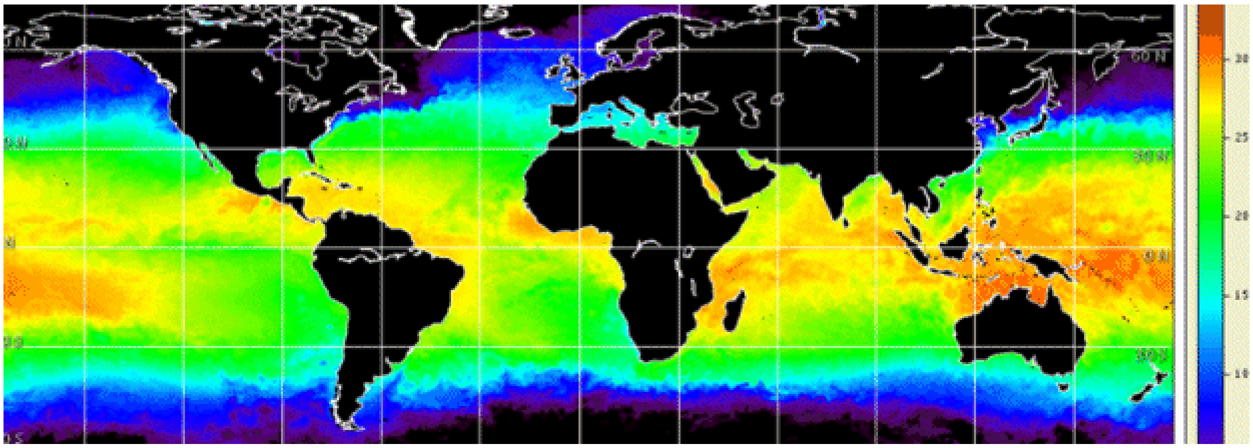


Example of a new climate data set from reprocessing polar orbiting images. The globes show the year-to-year variability in high clouds from data in July for four different years, 1983, 1988, 1993 and 1998. Areas with large amounts of high cloud are red, while areas with less high cloud are blue.

STAR will then reprocess data from other satellite instruments into long term data records in the coming years.

Sea Surface Temperatures

STAR is archiving high-quality data sets of sea surface temperatures (SST) over the next several years so that climate scientists may investigate the effect of the sea's temperature on global climates. 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 "Environmental Data Records" (EDR), will be built by STAR scientists. They will investigate the effect that higher resolution possible on future satellite instruments will have on these records. They will blend different types of satellite data to improve the quality and broaden the utility of sea surface temperature products.



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

STAR has also developed Climate Data Records (CDR) of sea surface temperatures from polar orbiting (AVHRR) satellite data from 1981 to the present, and from geostationary (GOES) satellite data from 1994. During that process, the effect that the diurnal cycle has on the sea surface temperature will be resolved. The team evaluates the satellite results against ground-based climatology and "re-analysis" products of the National Weather Service.

The atmospheric sounding instrument (AIRS) on NASA's satellites produces enormous volumes of data, approximately 35 GB/day of raw data. STAR provides to the climate community global gridded products at full spectral resolution, so that the community may evaluate whether existing algorithms are good enough or whether they 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. The uncertainties will be specified sufficiently well so that leaders may make informed decisions. • Climate-sensitive sectors of society, and the climate-literate public incorporate NOAA climate products into their decisions.

5.3 Weather and Water

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

Natural catastrophes (floods, severe storms, hurricanes, etc.) cause 7½ times more insured losses across the globe than man-made disasters. The work of STAR to develop the tools to observe and understand such catastrophes and their precursors assists those who predict them, and those who must plan for or manage disasters.

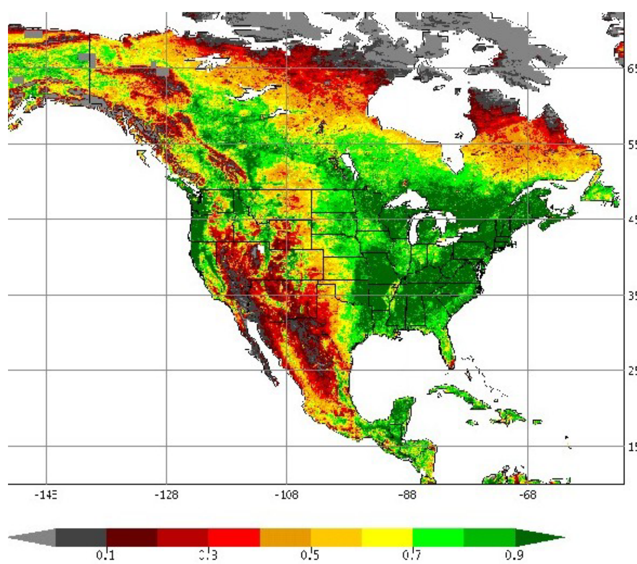
5.3.1 Assimilation of Data into Models

An extremely important use for atmospheric data from satellites is to set initial conditions for 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 (NWS). This Center's research aims to provide more accurate surface boundary conditions for operational prediction models.

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

They are 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, plus indices of vegetation derived from satellite data (figure at right), will be used in land surface models of the National Weather Service. Scientists are also investigating **cloud properties** for use as a possible product that NESDIS can deliver to NWS.

STAR scientists will improve the cloud mask product for **Sea Surface Temperature** (SST), already proven to be a valuable observation for use in weather forecasting. Algorithms which 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.



A Green Vegetation Fraction product for June 2003

Research in STAR has yielded better estimates of **ocean surface winds** around low pressure centers in high latitudes, which help to 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.

For all these products, STAR scientists study the effect that data having better spatial resolution and coverage will have on prediction models and forecast accuracy. New instruments to be put on NOAA's future satellites will transmit data of better resolution, in general.

STAR is developing the **Community Radiative Transfer Model (CRTM)** which will be directly 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 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.

The "Atmospheric Infrared Sounder" (AIRS) produces a huge quantity of radiance data every day. The weather forecast models of the Weather Service cannot ingest such a large volume of raw data, so STAR extracts a product from the raw AIRS data for the NWS that is ten times more compact, without measurably losing the information content. STAR will improve this process even more 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 the data display system of the Weather Service. Specifically, these products will include: clear-sky radiances, precipitable water, indices of atmospheric stability, satellite cloud products, cloud-top pressure, cloud-top temperature, effective cloud amount, and imagery depicting all of the above. When the NWS is ready to accept them, these full resolution products will replace the sounder products that NESDIS sends to the NWS at 50 km resolution.

5.3.2 Satellite Products

Most of the Center's research involves developing satellite products which support NOAA's Weather and Water goal, in order to assist the National Weather Service (NWS) to monitor current conditions in the atmosphere, to enable forecasters to predict the weather, and to warn of weather hazards. STAR tests the use of data from many instruments on both NOAA and non-NOAA satellites. Center 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 Sea Surface Temperature maps and forecast accuracy. The Center's SST products also support the Climate goal (see Sea Surface Temperatures and the Ecosystem goal (Section 5.1.1), as well as Weather & Water.

Rainfall Estimates

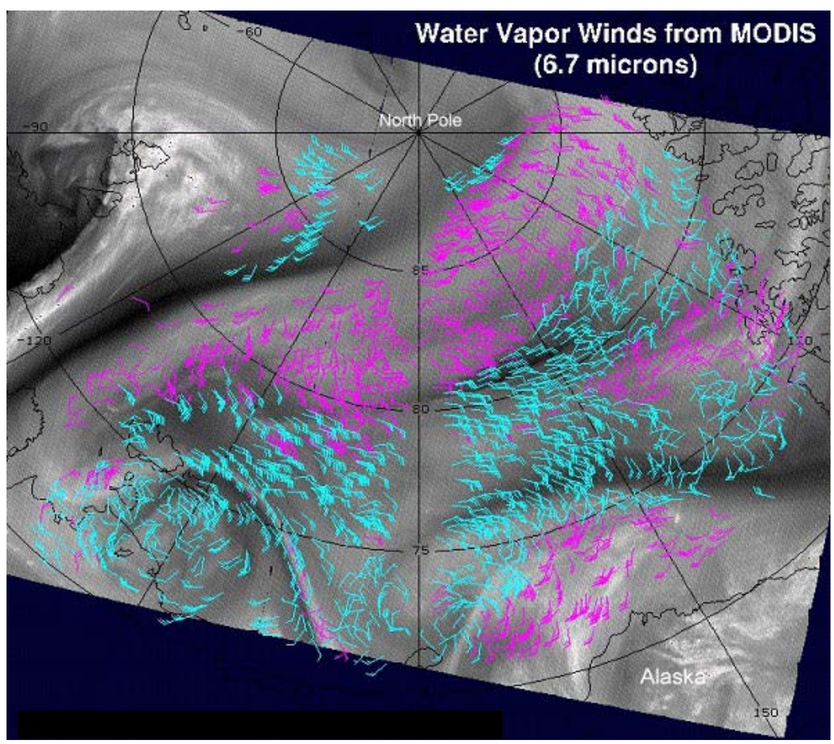
Observations of rain are important for a wide variety of applications, from the prediction of flash floods to the evaluation of long-term water supply. Since radar and rain gauges are available for only a small portion of the earth's surface (and mostly over land), STAR has supported weather forecasters and water-management agencies with precipitation products from satellite data for over 30 years. 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. For example, 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. This 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 dramatically improved, 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. The challenges are two fold: 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 is currently handing off this capability to its operational partners within NESDIS.

Windsat is a microwave instrument designed and built by the Navy, and 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).



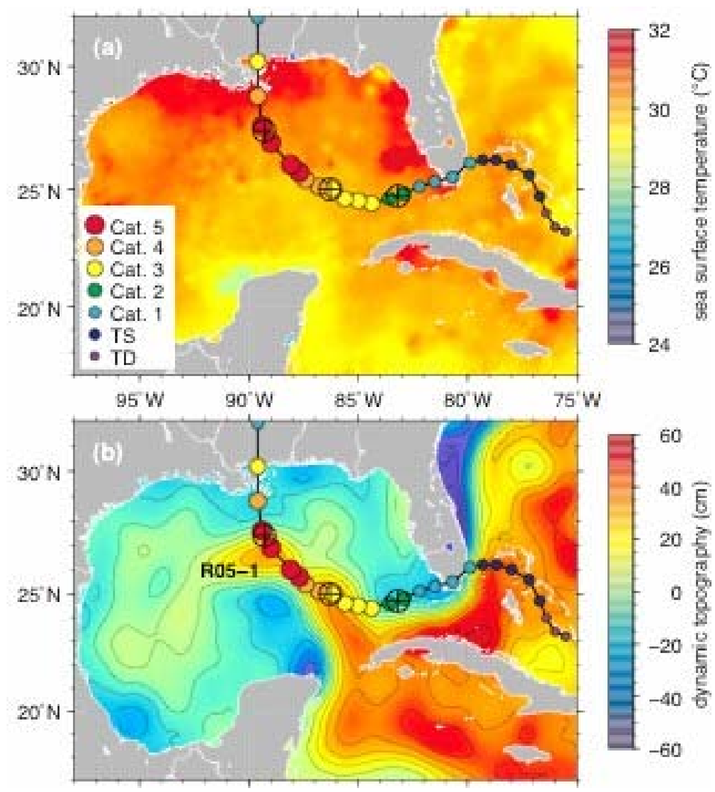
Winds derived from motion of features on MODIS images

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 them, and reach out to users. STAR investigates problems which degrade the quality of operational wind products, and finds solutions to correct them. A major objective is to have 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 real need is to estimate the current intensity, location and size of hurricanes, and once they form, to predict later changes in intensity.



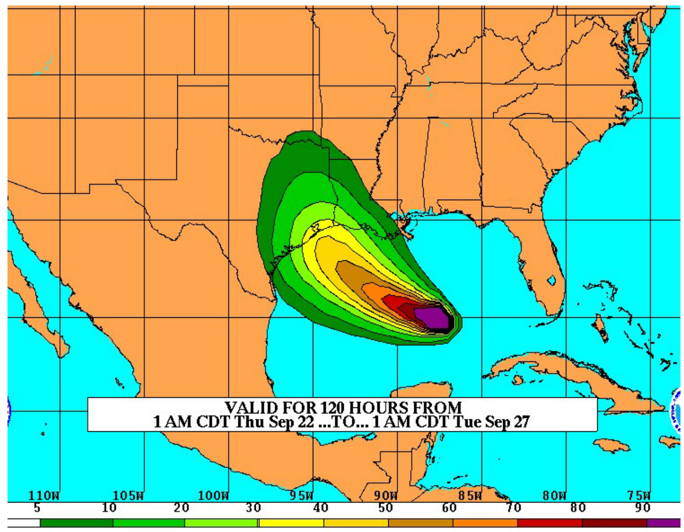
Hurricane Katrina intensified from Category 2 to 5 when it crossed regions of high oceanic heat content, which are regions of high topography detected by satellite altimetry (lower map). Coincident sea surface temperature (SST) data (top map) does ***not*** *clearly suggest a threat of hurricane intensification.*

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. These centers are co-located with regions of high heat content in subsurface waters. It is the depth of warm water, and not merely the temperature at the surface, that provides the reservoir of energy to intensify a storm (see figure above on "Hurricane Katrina").

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

In the 1990s, STAR worked with the NOAA Hurricane Research Division to develop a statistical model (known as the "Statistical Hurricane Intensity Prediction Scheme -- *SHIPS*") to predict the intensity of hurricanes. But 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, and also 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 (NHC) and the University of Miami to transfer these new hurricane forecasting products to the operational forecasting desk at NHC.

STAR can offer another valuable future product from 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.



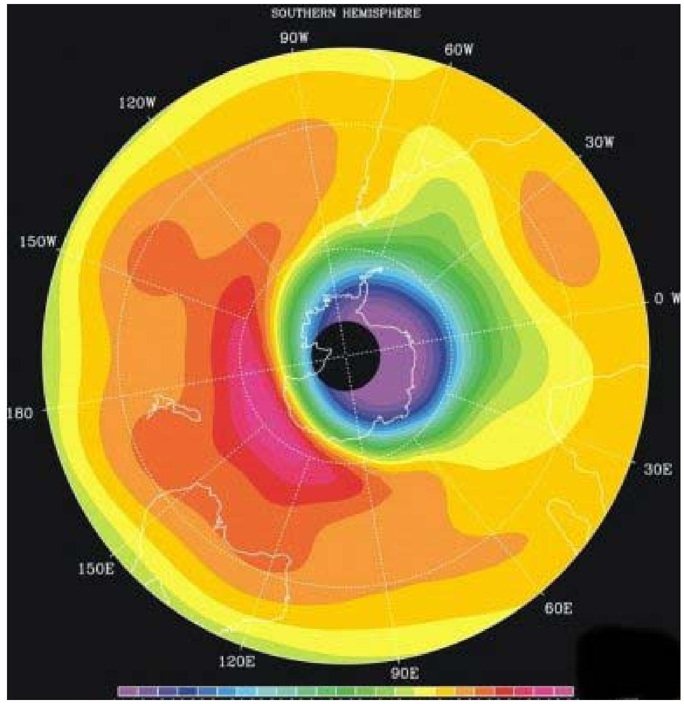
New Product: Probability (%) of winds exceeding hurricane force in a five day period, in Sep. 2005 for Hurricane Rita

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 zero to five days. The figure above 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.

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 the 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 in1980, a massive, continent-sized hole appeared over Antarctica and has grown during the intervening years. NESDIS, working with NOAA's Climate Prediction Center, 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).



Ozone concentration at 30 mb in southern hemisphere from SBUV-2 sensor on NOAA satellite, October 2001.

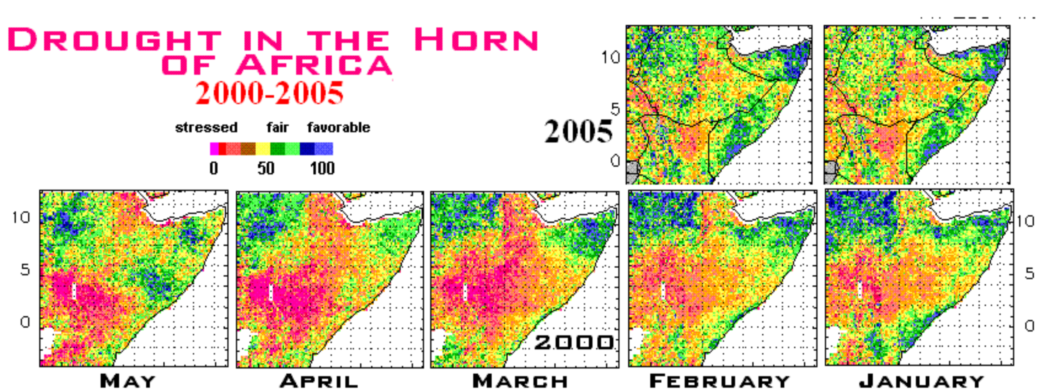
The image here shows the average ozone estimates at 30 mbar in the stratosphere for the southern hemisphere in October 2001. The estimate is based on measurements taken from a NOAA polar-orbiting satellite. The very low concentrations (indicated by the purple region) are evidence of severe ozone depletion. 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 radiation derived from geostationary (GOES) satellite data that will be a reference for evaluating the National Weather Service 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. The new product will include all the "flavors" of ultraviolet radiation: UV 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 information.

Vegetation Health

In Section 5.2.1, a STAR product known as "Green Vegetative Fraction" (GVF) was introduced. The GVF shows how much of the land surface is covered with actively growing vegetation. A different 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.



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 the image above). The Advanced Very-High-Resolution Radiometer (AVHRR), an imaging instrument on NOAA's polar satellites, measures the amount of solar reflection from green vegetation, which directly correlates to plant chlorophyll content. 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.

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, from geostationary satellite data. The goals are 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. That will include blending the products from polar and geostationary satellites and from multiple sensors and sources (including ground truth) to improve the fire products.

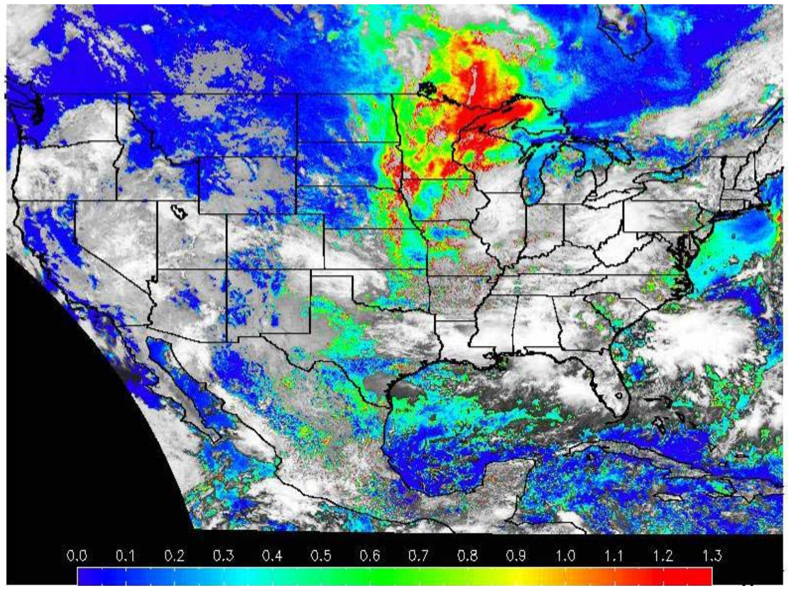
As new instruments are placed on new satellites, STAR determines their capability for detecting fires. Then the team determines trends in fire activity caused by deforestation, agriculture, and wildfires. Scientists investigate the effects of *biomass burning* on emission of aerosols and trace gases,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

The world has noted the success of STAR's product for wildfire monitoring, and has asked that the monitoring be extended around the world. 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. Fire products would be sent to users in real time.

Aerosols

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. The 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 the future sensors on board the next generation of NOAA's satellites.

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



Aerosol Monitoring for Air Quality and Forecasting

An example is this GOES satellite image at right showing the aerosol optical depth product 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.

STAR provides the near–real-time aerosol optical depth product for air-quality monitoring and the weather-forecasting community. The Environmental Protection Agency (EPA), the National Weather Service (NWS), and others use this product to track the movement of pollution plumes and verify forecasts of air quality.

Air Quality

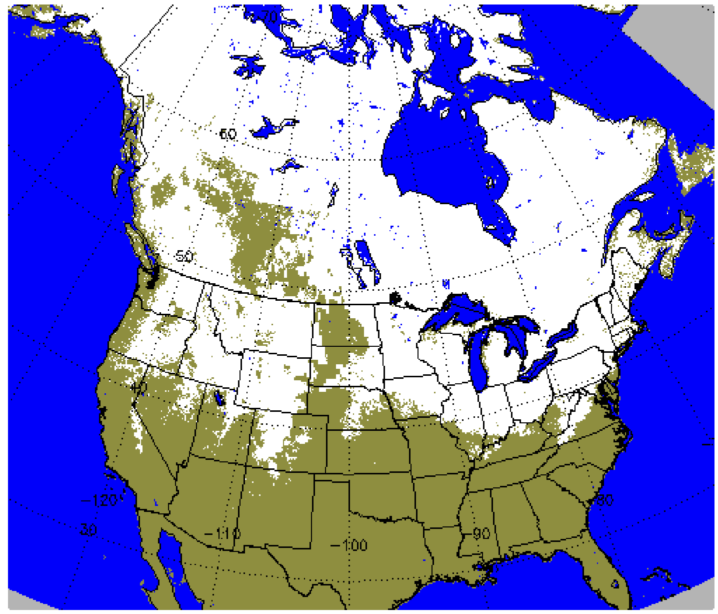
The U.S. Congress directed NOAA to issue nationwide hourly air quality forecasts. NOAA must develop and deploy nationwide forecasts for surface ozone by 2007 and for small particles (smoke and haze) by 2009. There are major uncertainties in forecasts of ozone and small particle concentrations, in part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

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. Objectives of the team are to provide 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 one 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. Pictures of ice and STAR's ice product are shown in the next section (5.4.1).

Snow Cover

NESDIS produces daily snow maps for several purposes. The maps are used in weather forecasting models, where they provide data needed for forecasting near-surface temperature and humidity. The snow maps are also part of the climate record, which should contain a long-term record of snow cover and its change over time. In the example below, the white area indicates snow; the green area indicates snow-free land.



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

STAR introduced the current NESDIS snow-mapping technology. Over 10 years the Center has developed a multi-sensor, multi-satellite snow product. The resulting maps are based on a mixture of data — an analyst draws the snow map using multiple sources of information. Because analyst-drawn maps are labor-intensive, STAR experiments with fully automating the snow maps in a way that retains the accuracy and reliability of the current product.

ACTIVITIES	NOAA PERFORMANCE OBJECTIVES	OUTCOMES
• Develop data products for assimilation into NWS numerical weather prediction models. • Develop and improve products which provide information on the earth's environment, and which are used to predict weather events. • Develop and improve products which provide a capability for NWS 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 the 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

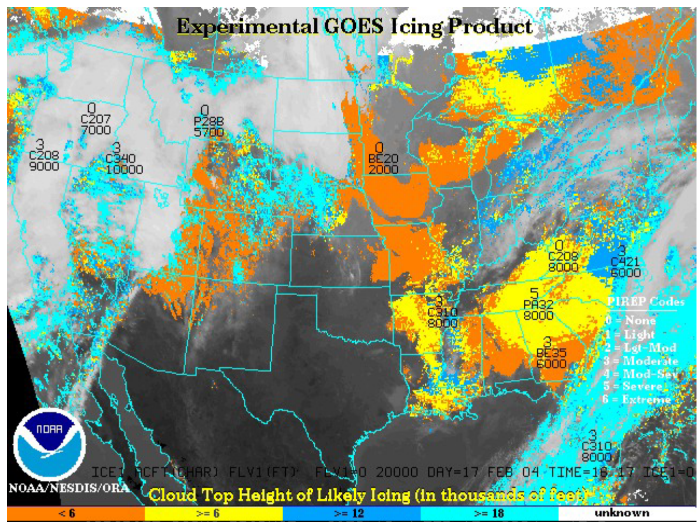
"Support the nation's commerce with information for safe, efficient, and environmentally sound transportation."

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 do this type of monitoring. STAR has long had a program in monitoring aviation hazards including icing, turbulence, fog, and convection. Below are some of the other hazards to transportation that STAR is working on.

5.4.1 Products

Aviation Hazards

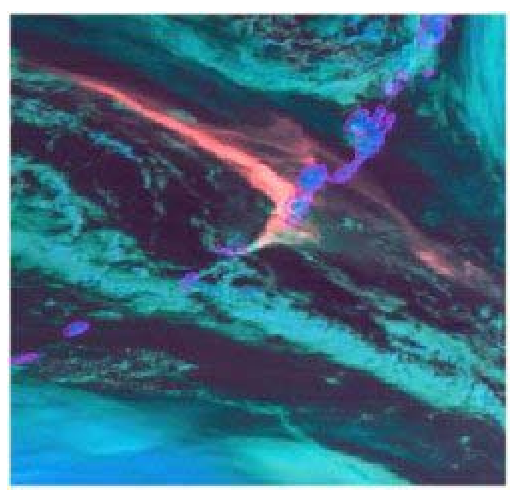
STAR scientists develop products to detect or forecast several hazards to aviation, including volcanic ash, fog and low clouds, and conditions associated with aircraft icing, turbulence, and convective wind gusts. Above is an experimental STAR product depicting the height of clouds where icing is likely 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.



Experimental GOES satellite product for Aviation Icing

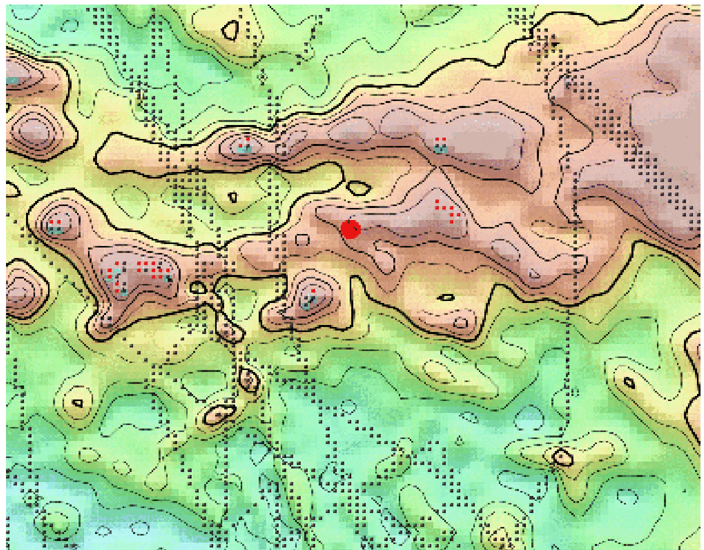
Volcanic Ash

Silicate ash emitted by volcanic eruptions travels long distances and threatens aviation by causing serious damage to jet engines and pitting windshields and edges of aircraft. STAR has shown that multi-spectral data from the Moderate-resolution Imaging Spectroradiometer (MODIS), on NASA's *Terra* and *Aqua* satellites, significantly improves detection of volcanic ash. The false-color image at right, having data from three MODIS infrared bands, shows volcanic ash from an eruption of Mt. Cleveland, Alaska in 2001; ash is shown in red, snow and ice in blue, and water droplet clouds in aqua. STAR will develop similar products to improve aviation safety using data from the next generation of NOAA satellites.



Ocean Bathymetry

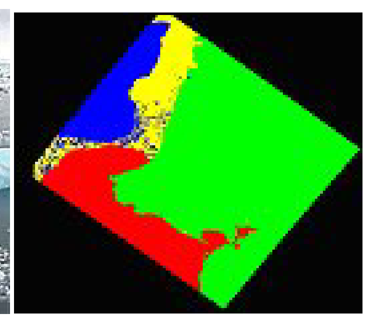
Safe and efficient ship transportation depends on having accurate marine charts that show the bathymetry (the depth of water and the topography of the sea bottom). STAR's Sea Surface Height team analyzes altimeter data from satellites to determine the precise sea level from point to point which can be used to add detail to bathymetric charts. The value of satellite altimetry data for detecting submarine hazards is revealed by the marine chart here. 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 feature was not detected by conventional soundings.



Depth contours of central Pacific Ocean, based on both conventional soundings (black dots) and satellite altimetry. Submarine crashed at red dot. This chart is 350 km wide.

Sea Ice

The National Ice Center (NIC), National Weather Service (NWS), and Integrated Program Office have requirements for monitoring sea ice. The Sea Ice science team in STAR creates products for these ice monitoring services. Its goal is to monitor daily the location, height and thickness of all sea ice at a resolution of 1 km, using microwave satellites with altimeters. The team also uses radar (*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 (below, 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 fishermen, transport and military vessels navigate safely through icy areas.



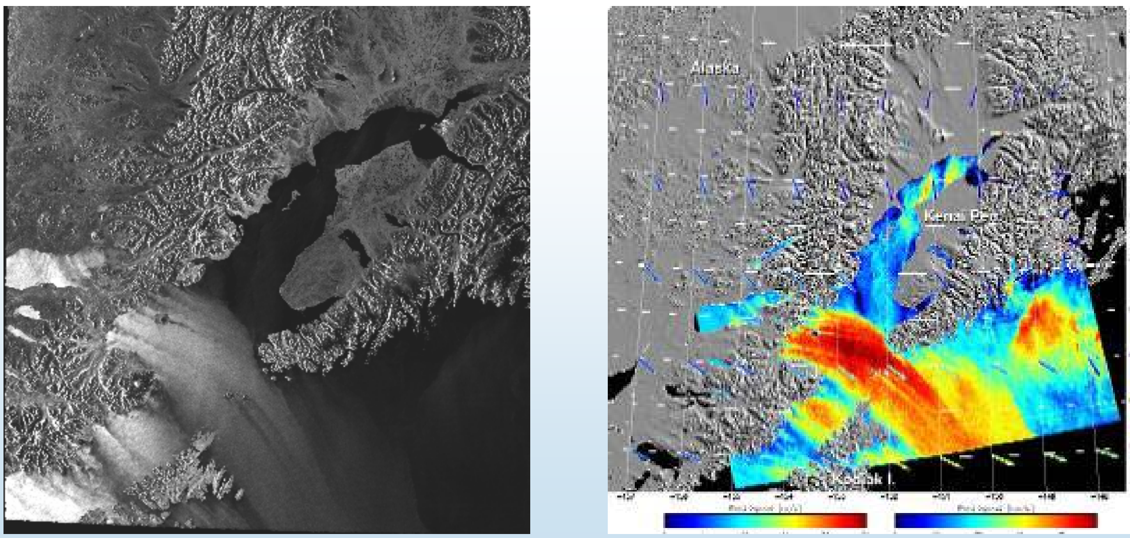
Using Satellite Wind Measurements to Improve Navigation

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 sea-going vessels. STAR is developing products that will lead to an operational system for several ocean products using **synthetic aperture radar** (SAR). In the figure below, the Alaskan Demonstration Project uses this radar to map high-resolution winds. Using algorithms developed by STAR, images (left) from the Canadian satellite

RADARSAT-1 are processed for wind speed and direction (right) to identify areas of potential danger. STAR will develop other SAR products for detecting vessels, mapping spills of oil, detecting coastal change, and monitoring ice.

Other Ocean Products

The Synthetic Aperture Radar will also offer a variety of other information about the sea useful to transportation interests. It is possible to inform people about the wind speed and direction at sea, about vessels on the high seas, oil spills, sea ice and ice on lakes and rivers, the height and frequency of waves, and many other features. Satellite Application science teams will develop products out of these observations, and where possible, will automate the process.



Using Satellite Wind Data to Improve Navigation

5.5 Critical Support for NOAA'S Mission

This strategic goal encompasses support from NOAA Offices which helps NOAA achieve its mission. The major contributions from STAR in this area include:

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

5.5.1 Design of Satellite Instruments

Advanced Baseline Imager on the next generation of GOES satellites

Center scientists participate in designing revolutionary new instruments to be flown on the next generation of geostationary satellites, and determine the best way to use their data to meet 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.

5.5.2 Build Quality into Data: Instrument Calibration

This Center supports the calibration of all data in NOAA's satellite operations, with these goals:

a. To calibrate the operational data on current satellites:
   - The polar orbiting satellites in low orbit
   - The imager and sounder in high, geostationary orbit
b. To calibrate data that will flow from future NOAA satellites
c. To calibrate old data that is re-processed from the archives
d. To expand current capability in instrument calibration

   As examples, 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 (NIST).

   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.

e. To set a new standard for the quality of sea surface temperature data (SST)

   STAR has created a comprehensive system of quality control for this parameter. The team runs statistical checks to ensure that the SST 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 in 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, a lightning mapper, a solar imager and a space environment monitor. Perhaps the boldest new instrument is the *"Hyperspectral Environmental Suite"* (HES), with which NOAA will be capable of producing 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 shorter wave length light than present instruments use, which will tell us about different properties of ocean and land surfaces.

A new imaging instrument, the "Advanced Baseline Imager" (ABI) will provide greater area coverage of the surface at more frequent intervals.

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 “Hyperspectral Environmental Satellite” (HES) data compression project is to offer a flexible solution to handle the large data rates of the next generation of geostationary sounders. This can be done by being the leader in the field of high spectral resolution infrared data, and in 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 “Global Earth Observation System of Systems” (GEOSS) has led NOAA to participate in many other interagency and international programs of earth observation. NOAA is preparing an Integrated Global Environmental Observation and Data Management System, for the “Integrated Earth Observing System” (IEOS). NOAA may 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.

Integrated systems such as the three mentioned above are central to NOAA mission goals, since integration of systems and data will yield better products. This Center contributes to all of these new systems, and 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 products for the hydrological cycle, from passive satellite microwave data. Some of the most important products are precipitation rate, total precipitable water, liquid path and ice water path in clouds, snow cover, equivalent water in snow, sea-ice concentration, and land surface temperature.

Geostationary (GOES) Imager and Sounder Products

The current generation of geostationary satellites (GOES) generates many products from both the imaging and the sounding instruments. STAR will update them and generate new products for weather forecasters and developers of weather prediction models, for the aviation industry, University scientists, other government agencies, and international institutions.

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 intercompare the radiation measurements from the high-orbit geostationary satellites and the low-orbit, polar orbiting satellites.

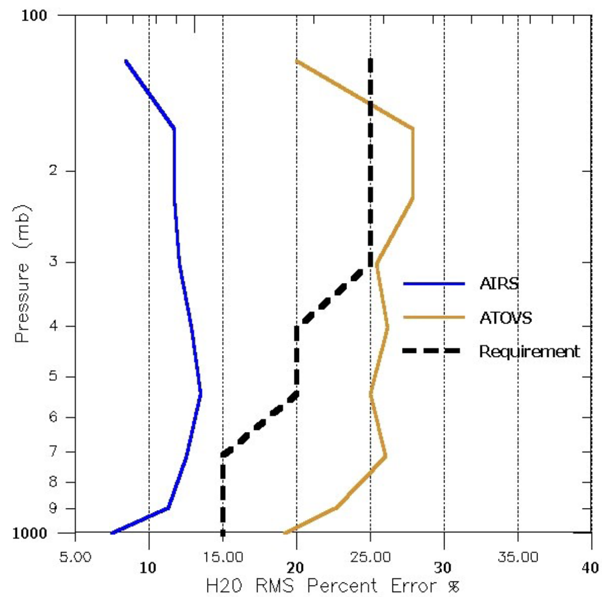
STAR is investigating problems which have degraded the quality of some operational products. To do this, the plan is to verify the accuracy of existing and new products; maintain parallel processing of experimental products; and follow a robust and repeatable path for passing new algorithms and products 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

In "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 attain 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* has been termed "cloud clearing."



The best atmospheric soundings today come from the "Atmospheric Infrared Sounder" (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 the diagram on this page, the measurement errors of the AIRS sounding (blue curve on left) are significantly smaller than the errors of the now-operational ATOVS sounding (yellow curve on right). In fact, the errors of the AIRS sounding are less than the requirement. These soundings measure the amount of water vapor in the low and middle 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), having invested many resources to develop algorithms and verify the results. These results are termed "*cloud cleared radiances*" (CCR). 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 therefore degrades confidence in the end results; and if the AMSU fails, no soundings can be produced. So 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. But these efforts may help us to achieve the very desirable goal of sounding the atmosphere from a high-orbit, geostationary satellite like the GOES. The next generation GOES-R is now being designed, and unfortunately, it appears that it will fly without a microwave instrument. So 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 a microwave instrument is unlikely on the GOES-R, the innovative techniques being explored for all three generations of the polar orbiting sounders—the present AIRS system (above), 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, called the "Infrared Atmospheric Sounding Interferometer" (IASI). It is scheduled for launch in 2006 on the European *Metop* satellite. Having thousands of channels (about 8600), 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. That allows good cross-calibration between the current operational sounders and the experimental IASI sounder.

In order to realize these benefits from the European instrument, STAR will undertake three actions:

- Intercompare 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. Also, 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," or *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 re-calibrated and perhaps re-navigated. 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 Longwave Radiation (OLR)

A long-term record of outgoing longwave 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 longwave radiation from the three generations of sounding instruments described above (HIRS, AIRS, and CrIS). Furthermore, this data record should be compatible with the Earth Radiation Budget (ERBS) data that will be available on the future NPOESS satellites. The estimates will be much improved over the longwave measurements now available.

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 way. 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, in order 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 person-hours of training since 1999. STAR continues to provide new training sessions in VISIT.
- The World Meteorological Organization (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 (NWS) 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 The Cooperative Research Program is achieving this goal.

5.6.2 Information Technology

In May 2005, STAR conducted a week-long Information Technology (IT) Infrastructure Study work session. The study group had representatives from STAR, its Cooperative Institutes, private sector partners, and other science partners. The results were published in a 107-page Report describing the Group's recommendations for IT Enterprise Architecture and IT Governance in this Center. The goal is to have an IT Enterprise Architecture which 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 of the data.

By the end of FY2005, STAR will have established its IT governance. Four groups will help the Deputy Director govern IT: An IT advisory committee, a data management group, a configuration management group, and a web services group. Three of these groups will be subcommittees of the IT Advisory Committee. These groups will implement the recommendations of the study group over the next 2 years.

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" (IPT).

5.6.4 Science Management

Every year STAR prepares three levels of planning documents. They are: this STAR Road Map providing an overview for the entire Center, the Division Road Maps with more detail for each Division's activities, and the Research Project Plans having specific detail 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 Divisions' requirements, scientific research priorities, customers, partners, resource needs and ways of measuring success. The lead scientists for each science project prepare the Research Project Plans (RPPs) to describe key aspects of their research for the next five years. Appendix A lists all 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:

- **Science 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. Then STAR aligns its priorities and activities with NOAA goals. NOAA also develops performance measures for its programs that attempt to achieve strategic goals. At a high level, the goals of STAR are to:

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

At a more detailed level, 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 suggests that the STAR product improved the accuracy of the forecast.)
- Percentage of STAR products transferred from research into operations

STAR has identified twenty one performance goals indicated in the following table. Each goal is associated with a measure of performance

.

STAR Unique Performance Goals and Measures

NO.	Goal	Priority	Performance Goal	Performance Measure
1	WW	IGEO	Develop new sources of data for assimilation into numerical weather prediction models	No. of new data sources actually assimilated into weather models
2	ALL		Using satellite data, develop products which support NOAA mission	No. of new or altered products transferred to operations
3	ALL		Using satellite data, develop techniques which support NOAA mission	No. of new techniques transferred to operations
4	CS	SS	Review instrument specifications for satellite acquisition programs	No. of design reviews and number of comments
5	CS	SS	Calibrate new instruments designed for satellite acquisition programs	No. of new algorithms developed to calibrate new instruments
6	CS	SS	Reduce risk in new satellite systems	No. of contributions to programs
7	CS		Build quality into NOAA satellite data	No. of algorithms changed to improve calibration
				No. of data sets validated
8	CS		Develop accurate, long-term data sets for research	No. 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
				No. of management tools implemented
10		IGEO& DM	Support NOAA Data Programs and Committees	No. of committee contributions
11		EL	Educate and inform the public and special interests on the use of satellite data and related research	No. of education and training activities
12		EL	Publish quality papers which describe STAR research and advancements	No. of papers published
13		EL	Develop training tools which can be used for satellite education	No. of training tools developed
14		EL	Provide training on satellite applications	No. of students trained
15		EL	participate in national, international conferences	No. of conferences attended
16		IL	Support national and international committees which promote integration and use of satellite data	No. of committees supported
17		IL	Share satellite data and information among international partners	No. of cases sharing data/information with intl. Partners
18	CS		Improve "Research to Operations"	No. of R2O efficiencies implemented
19	CS		Improve STAR IT Management	No. of IT efficiencies implemented
20	CS		Improve STAR Management of Science	No. of management tools implemented
				Decrease monthly % deviation from spending plan
			Priorities: IGEO = Integrated Global Environmental Observation SS = Ensure sound, state-of-the-art research WF = Work force EL = Environmental literacy IL = International leadership	**Goals:** WW = Weather and Water CS = Provide critical support for NOAA's mission ALL = All five NOAA goals

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 it should be 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.

Satellite technology for Earth observation will go through three major upgrades in the next fifteen years. They include 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 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 was collected from satellite platforms. These improvements will continue.

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

By collaborating with users (for example, organizations that create weather prediction models), STAR can test these simulated data sets to assess what might result if these new observations were 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 in this Center, but its possibilities are just beginning to be appreciated. The goal of EVP is to empower 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 (in the GOES series) and polar-orbiting satellites (in the NOAA series), and to add layers of additional information over the imagery. Most products in STAR consist of layers of information taken from the various channels of data from the GOES and NOAA 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, one must simulate complex data sets, and utilize multiple processors for complex operations. The Center's IT specialists must also anticipate the growing problem of information security, to ensure that its computers and data remain available.

Once scientists have products from the new satellite technologies of tomorrow, the information they contain must be visualized on computer systems that can handle these much larger data sets, then the information must be distributed. Two ways that the staff at STAR can make sense of the new products, verify their accuracy, and then distribute the meaningful content to end users are: (1) to exploit three dimensional (3D) visualization programs, and (2) to use enhanced geographical informational systems (GIS). The web-based training program also teaches the use of the enhanced satellite technologies and products.

New and improved technologies permit scientists to create new and improved science. STAR uses Information Technology 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; in order to do that, a nation needs a coordinated network of satellites, in various orbits, with many types of advanced instruments, each of which communicates data quickly. Therefore the Center has a large and never-ending task of calibrating these instruments. This is done 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 one can calibrate different instruments in many different orbits and paths. 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 merger 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, and STAR can help decision makers to find the best solution.

Center scientists need improved access to global observations from conventional, *non-satellite* sources, to ensure that its 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, which affect these international activities:

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

STAR services the organizations that service these industries, creates new information products, and enables its customers to use new data. NOAA is embracing more cross-disciplinary approaches in its quest to understand the physical and biological processes on Earth. Here are some of the ways that the work of STAR benefits the world:

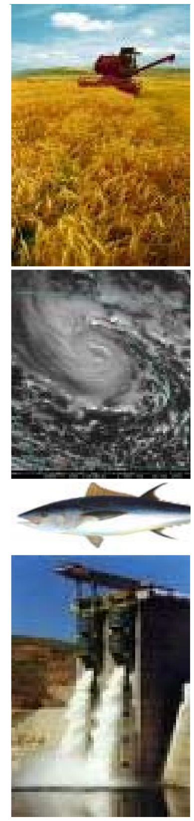
- Monitoring air quality is more effective if the observations are in real time. Other specialists are then able to make accurate forecasts that, days in advance, will enable society to mitigate the health effects of poor air quality by managing transportation demand and reducing energy use.
- Observations of the oceans are essential inputs to accurate climate forecasts. It may become possible to predict long-term drought.
- Monitoring the water quality in every watershed and coastal area, in real time, could provide farmers with the information they need to apply the correct amount of fertilizers and pesticides to maximize crop yield at lowest cost. The intention is to support both healthy ecosystems, increased yields from U.S. fisheries, and coastal tourism.

Natural disasters cost society a great deal. Groups from farmers to emergency managers need advance information to plan their responses and relief activities. Events such as Hurricane Katrina, forest fires, summer urban heat emergencies, and erupting volcanoes demonstrate that it benefits the United States to create tools to protect the population and commerce of the nation. Data from US 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 forecasts of surface temperatures and moisture 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 fruit 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 vehicles.

STAR's applied research and support to operations is ultimately measured by 9 societal benefits. The following areas guide the vision of STAR's program:

- Improve Weather Forecasting
- Reduce Loss of Live 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



Ultraviolet (UV) radiation from the sun is a 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 earth's ecosystems are not completely understood. While humans can choose to protect themselves by avoiding the sun at noon, plants and animals are not so fortunate. Studies have shown that increased UV radiation can cause significant damage to small animals and plants. Marine phytoplankton, fish eggs, and young plants with developing leaves are particularly vulnerable to damage from overexposure to UV. Clouds and ozone have a large effect on UV radiation levels, but cloudy skies often do not offer significant protection from UV. Satellites easily monitor clouds, cloud height, ozone levels, and other factors that affect the intensity of UV radiation. STAR research on monitoring ultraviolet radiation using satellites will take account of all of this, and deliver a single UV product.

The international scientific community has discovered that fires set by humans impact 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 in the long-term.

Finally, a National Academy of Sciences Report on Public Health Systems and Emerging Infections recommended that the public health community "increase the use of novel surveillance systems and modeling techniques to help predict, detect, or monitor disease trends, environmental and climatic conditions or genetic shifts that suggest disease outbreaks and facilitate epidemiological investigations." When STAR identified potential outbreaks of the West Nile Virus, the Center 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 the Agency and the Nation to meet the five strategic goals of NOAA in climate, ecosystems, weather and water, commerce and transportation, and critical support for the Agency's mission.

The Center supports a host of activities in remote sensing that improve 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 them into tools for easy transfer into practical applications inside and outside the federal government.

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 (JCSDA) Community Radiative Transfer Model, Developed for Satellite Data Assimilation and Climate Applications
- GOES Surface and Insolation project
- Development of a CERES Outgoing Longwave 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 (SST) Science Team
  - Environmental Data Records
  - Climate Data Records
  - SST Quality Control and Quality Assurance, Calibration and Validation
  - SST Applications

- Sea-Surface Roughness (SSR) 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 (SSH) Team
  - Altimeter Data Sets
  - Ocean Dynamics
  - Marine Gravity and Bathymetry
  - Climate

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

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

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 (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 the Cooperative Research Programs (CORP) Division. 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 Training ("SHyMet")
- 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

Cooperative Agreement Proposal

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) 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 Advance 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 Acronyms

ABBA	Automated Biomass Burning Algorithm
ABI	Advanced Baseline Imager
ABS	Advanced Baseline Sounder
ACARS	Aircraft Communications and Reporting System
AE	Auto-Estimator
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
AMSU-A	Advanced Microwave Sounding Unit -- A
AOD	Aerosol Optical Depth
ARAD	Atmospheric Research and Applications Division
ArcGP	Arctic Gravity Project
ASADA	Automated Smoke and Aerosol Detection Algorithm
ASOS	Automated Surface Observing System
ATOVS	Advanced TIROS Operational Vertical Sounder
AUTEC	Atlantic Undersea Test and Evaluation Center
AVHRR	Advanced Very High Resolution Radiometer
AWIPS	Advanced Weather Information Display System
CCRS	Canada Center for Remote Sensing
CICS	Cooperative Institute for Climate Studies
CIORS	Cooperative Institute for Ocean Remote Sensing
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CLAVR	Clouds from AVHRR
CMDL	Climate Monitoring and Diagnostics Laboratory
CMIS	Conically Scanning Microwave Image/Sounder
CMOD4	C-Band Model Function
CNES	French Space Agency
COMET	Cooperative Program for Operational Meteorology
CONUS	Continental United States
COSMIC	Constellation Observing Satellites for Meteorology, Ionosphere, and Climate
CPC	Climate Prediction Center
CPUE	Catch Per Unit Effort
CrIS	Cross-track Infrared Sounder
CRAD	Climate Research and Applications Division
DAAC	Distributed Active Archives Center
DoD	Department of Defense

DAO	Data Assimilation Office
DHW	Degree Heating Weeks
DMSP	Defense Meteorological Satellite Program
DWL	Doppler Wind Lidar
EDC	EROS Data Center
EMC	Electromagnetic Compatibility
EOS	Earth Observation System/Satellite
EROS	Earth Resources Observation System
ERS	European Remote Sensing
ETL	Environmental Technology Laboratory
EUMETSAT	European Meteorological Satellite
FTP	File Transfer Protocol
GDAS	Global Data Assimilation System
GDR	Geophysical Data Record
GEWEX	Global Energy and Water Cycle Experiment
GIS	Geographical Information System
GOES	Geostationary Operational Environmental Satellite
GOME-2	Global Ozone Monitoring Experiment
GPCP	Global Precipitation Climatology Project
GPSOS	GPS Occultation Sensor
GRAS	GPS Radio Atmospheric Sounder
GSC	Geological Survey of Canada
GSFC	Goddard Space Flight Center
GVI	Global Vegetation Index
HIRS	High-Resolution Infrared Radiation Sounder
HRS	High-Resolution Infrared Radiation Sounder
IASI	Infrared Atmospheric Sounding Interferometer
IFCT	Instrument Functional Chain Team
IFFA	Interactive Flash Flood Analyzer
IGBP	International Geosphere Biosphere Programme
IGOS	Integrated Global Ocean Observing Strategy
IMI	Irish Marine Institute
IOCCG	International Ocean Color Coordinating Group
IT	Information Technology
JPL	Jet Propulsion Laboratory
LDAS	Land Data Assimilation System
LRC	Lesser Regional Contingency
LSA	Laboratory for Satellite Altimetry

MAS	MODIS Airborne Simulator
METOP	Meteorological Operations Platform
MOBY	Marine Optical Buoy
MODIS	Moderate Resolution Imaging Spectro-Radiometer
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCEP/NCAR	National Centers for Environmental Prediction/National Center for Atmospheric Research
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite, Data, and Information Service
NIMA	National Imagery and Mapping Agency
NIST	National Institute of Science and Technology
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRCS	Normalized Radar Cross-Section
NSF	National Science Foundation
NWP	National Weather Prediction
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OH	Office of Hydrology
OLR	Outgoing Longwave Radiation
OPT	Ozone Processing Team
ORA	Office of Research and Applications
ORAD	Oceanic Research and Applications Division
OSDAD	Office of Satellite Data Processing
OSDPD	Office of Satellite Data Processing and Distribution
OSSE	Observing System (Simulation) Experiment
PATMOS	Pathfinder Atmosphere
POES	Polar-orbiting Operational Environmental Satellites
POP	Product Oversight Panel
QPE	Quantitative Precipitation Amounts
QPF	Quantitative Precipitation Forecasts
RAMMT	Regional and Mesoscale Meteorology Team
RAMSDIS	Regional and Mesoscale Meteorology Team Advanced Meteorological Satellite Demonstration and Interpretation System

RFI	Radio Frequency Interference
SAR	Synthetic Aperture Radar
SBUV/2	Solar Backscatter Ultraviolet Spectral Radiometer, MOD 2
SECW	Southeast CoastWatch Program
SRSO	Super-Rapid Scan Operations
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature
TIROS	Television and Infrared Observation Satellite
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment (A Sensor)
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TST	Technical Support Team
UKMO	United Kingdom Meteorological Office
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USWRP	United States Weather Research Program
VCI	Vegetation Condition Index
VIIRS	Visible/Infrared Imager/Radiometer Suite
VIRS	Visible Infrared Scanner
VISIT	Virtual Institute for Satellite Integration Training
WINDEX	Wind Experiment