TESTIMONY ON
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION'S
FY 2003 BUDGET
REGARDING
SATELLITE DATA UTILIZATION AND MANAGEMENT

BY THE
UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE
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BEFORE THE

THE SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY AND STANDARDS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

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Thank you, Mr. Chairman, and members of the Subcommittee for providing us the opportunity to testify on the President's FY 2003 Budget Request for the National Oceanic and Atmospheric Administration (NOAA) and specifically NOAA' Satellite Data Utilization and Management activities.

The FY 2003 Budget Request supports and enhances the goals of the President and the Department of Commerce's activities to provide satellite, data, and information products that support public and private services and contribute to the quality of life of all Americans. In addition to supporting the Nation's economic growth, satellite, data and information products contribute to National and Homeland Security efforts, as well.

Today, I will discuss with you how NOAA is addressing the challenges, significant opportunities, and initiatives underway to exploit the current and future streams of satellite data. I will highlight the following:

- Value of NOAA Satellite Data;
- Overview of NOAA's Satellite Programs
- FY 2003 Funding Request;
- Satellite Data Utilization and Data Management;
- Deficiencies in FY 2002 Satellite Data Processing and Distribution;
- NOAA's Plans to Ensure Maximum Use of NPOESS Data; and
- Archiving challenges From NPOESS and NASA EOS Satellites

A. Value of NOAA's Satellite Data

NOAA's services promote, protect, and enhance the Nation's economy, security, environment, and quality of life. NOAA's satellite observations are major contributors to these services. Since the launch of the first weather satellite, Television Infrared Observation Satellite (TIROS-1), on April 1, 1960, NOAA, including its predecessor organizations, has been providing the Nation with continuous global environmental observations.

The data and products derived from these satellite observing platforms have not only revolutionized our ability to forecast the weather, but have also contributed to our understanding of climate, the oceans, and other aspects of the Earth's environment. Satellite imagery and derived products have become a critical data source for severe weather forecasting and are essential for the tracking and prediction of hurricanes and typhoons. To quantify the impact of satellite data, I offer the following example: Today, our skill for 5-day forecasts equals our skill for 3-day forecasts in 1985. This improvement can be attributed to improved modeling and global observations - of which 97% is derived from satellites. As part of our future plans, our goal is to make accurate forecasts to 7 days and beyond. This goal can only be realized with advances in modeling and new satellite observations.

Virtually every sector of the Nation's economy relies upon rapid and reliable access to environmental data and information. NOAA environmental data form the basis for making decisions that have far-reaching economic consequences at local, regional, and global levels. These data are distributed to, and used by government, commerce, industry, science, engineering, and national defense. NOAA contributes to the national economy by providing environmental data for energy distribution, the development of global food supplies, and management of natural resources. Our environmental satellite observations are an important contribution to U.S. national security by providing military users real-time and near real-time information for aircraft, ships, and facilities around the world.

For climate observations, the President has called for programs which can reduce the uncertainty of the climate. While models play a role, calibrated global observations are key to our understanding of climate. Satellites are the only global observing platform for much of the atmosphere, oceans, and land surface.

B. Overview of NOAA's Satellite Programs

NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), the Nation's only civil operational space organization, operates the United States' geostationary and polar-orbiting environmental satellites. NESDIS includes three National Data Centers, which manage the largest collection of atmospheric, geophysical, and oceanographic data in the world.

Geostationary Operational Environmental Satellites (GOES)

NOAA operates two environmental satellites in geostationary orbit above the Equator, known as the Geostationary Operational Environmental Satellites (GOES). They monitor North and South America and most of the Atlantic and Pacific Oceans. The two GOES satellites operate day and night to provide satellite images and critical data to users throughout the Western Hemisphere.

To keep pace with the growing needs for GOES data and products, NOAA is evolving its geostationary remote-sensing capabilities with the development of GOES-R, scheduled for launch in 2012. Upgrades to NOAA's environmental observation requirements in the GOES-R series focus on greater temporal and horizontal resolutions, improved product accuracies, and extended geographical coverage.

Polar-orbiting Operational Environmental Satellites (POES)

Complementing the geostationary satellites are the polar-orbiting satellites, known as Polar-orbiting Operational Environmental Satellites (POES). Continuously circling Earth in sun-synchronous orbit, these satellites support global weather and marine forecasts. Operating as a pair, these satellites ensure that observations for any region of Earth are no more than 6 hours old. The METOP satellite partnership between NOAA and its European partners is designed to continue satellite data availability through joint partnership in our polar satellite program.

The Nation's responsibility for continuity of operational polar-orbiting services lies with the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program. This is a joint Department of Commerce (DoC)/NOAA, Department of Defense (DoD), and National Aeronautics and Space Administration (NASA) program merging the current POES and Defense Meteorological Satellite Program (DMSP) systems into a common system of polar satellites. The goal is to provide meteorological, oceanographic, terrestrial, climate, space environment and other environmental data products for both civilian uses and military operations.

The GOES, POES and NPOESS programs are critical building blocks to the development of an integrated observation strategy for the 21st Century.

II. <u>FY 2003 Funding Request</u>

The President's FY 2003 Budget Request for NOAA is $3,330.5 million in total budget authority. Of that amount, the FY 2003 request for NOAA's Satellite and Information Service is $764.7 million. The funding requested in the FY 2003 President's Budget Request will allow NOAA to ensure that our mission for environmental stewardship, assessment, and prediction of the Nation's resources is fulfilled, and continues to excel in our science and services to the American people.

Of the total $764.7 million in the NESDIS budget request, $360.2 million (47.1%) is allocated to polar orbiting satellites, $227.4 million (29.7%) to geostationary satellites, $91.8 million (12%) to environmental satellite observing services, and $60.1 million (7.9%) to NOAA data centers and information services. The remaining $25.2 million (3.3%) goes for construction and other costs. Later in my testimony, I will cover funding for specific initiatives in FY 2003 for satellite data utilization.

Table 1
FY2003 PRESIDENT'S BUDGET
(in millions of dollars)

NOAA Line Office	Amount
National Ocean Service	$410.9
National Marine Fisheries Service	741.2
Office of Oceanic and Atmospheric Research	307.5
National Weather Service	800.8
Program Support	328.4
NESDIS	**764.7**
Other	-23
Total NOAA	**$3,330.5**

NESDIS

Budget Category	Amount
Environmental Observing Services	$91.8
Data Centers & Information Services	60.1
Polar Orbiting Systems	360.2
Geostationary Systems	227.4
Construction & Other	25.2
Total NESDIS	**$764.7**

III. Satellite Data Utilization and Data Management

In support of NOAA's mission, it is critical to ensure that the data and products from our satellites are responsive to users' needs in terms of timeliness, quality, and delivery. To address this challenge, NESDIS has been re-engineering its planning processes to fulfill our end-to-end responsibility. Our improved planning approach looks systematically at the full program cycle: from requirements and planning, to acquisition, launch, command and control, real-time product development, archive and access, assessments, and user services.

A major part of the end-to-end approach includes a comprehensive requirements process. NOAA's satellites are just one of the major observing tools we use to meet our overall mission of environmental monitoring and marine resource stewardship. This requirements process will lead us to defining a single civilian space architecture capable of serving NOAA's diverse requirements for space-based environmental observations. Our program planning and funding requests will be developed in the context of this end-to-end approach.

With improvements in satellite instrumentation, and the growth of a more sophisticated and knowledgeable user community, NOAA faces major challenges to provide an ever increasing number of satellite products to a broader and more demanding user base. Explosive growth is occurring in both the number of research and operational environmental satellite missions in orbit.

NESDIS presently acquires and processes data from NOAA's two GOES and two POES satellites, as well as from DoD's two DMSP polar orbiting satellites. Additionally, NESDIS acquires and processes data from a number of non-NOAA, non-DoD spacecraft. The satellite data acquired each day by NESDIS total around 130 gigabytes, and enable NOAA to provide urgently needed information to our customers.

Data from non-NOAA research and operational satellites provide information capabilities not available from NOAA spacecraft that can be used to allow us to improve support for our diverse user community. In addition, our scientists, analysts, and future systems designers can conduct risk reduction assessments in preparation for the introduction of a future NOAA operational capability.

Some of the non-NOAA instruments for which NOAA processes data include:

- improved imagery, surface temperature data, and advanced atmospheric soundings from the NASA Earth Observing System (EOS) Terra and Aqua missions;
- Synthetic Aperture Radar (SAR) providing all weather, day and night images from the Canadian RADARSAT satellite;
- Meteosat winds and imagery from Europe;
- Japan's GMS winds and imagery;
- ocean surface wind measurements from NASA's QuikSCAT and Europe's ERS; and
- ocean color data from the commercial ORBVIEW-2 satellite.

Currently, nearly 300 POES and about 200 GOES products are distributed to a variety of Federal, international, state, university, private, and public users. Many of these products are created many times throughout the day, such as the GOES high density winds, which are created 48 times in a 24-hour period. As a result of an increasing number of satellite products and applications, NESDIS serves and interacts with a growing number of user communities.

These communities include:

- Weather forecast offices throughout the Nation and the Western Hemisphere;
- NOAA's Environmental Prediction Centers specializing in hurricane, severe storm, aviation, space environment, hydrological, ocean, and climate forecasts and environmental modeling;
- NOAA Research Laboratory; the national and international climate community concerned with climate change and ozone levels;
- Federal, state, and local resource managers responsible for coastal environmental monitoring; officials reacting to environmental hazards, including fire fighting authorities, including but not limited to:
    - Federal Aviation Administration (FAA) and the aviation community;
    - U.S. Forest Service (USFS)
    - Federal Emergency Management Agency (FEMA)
    - National Interagency Fire Center and all sectors of the wildland fire-fighting community
    - U.S. Coast Guard, including search and rescue efforts, and support to shipping and fishing industries
    - U.S. Department of Agriculture (USDA) for agricultural and drought monitoring
    - NASA
    - U.S. Geological Survey
    - U.S. Department of State and U.S. Agency for International Development in support of U.S. foreign policy directives
    - U.S. Department of Energy
    - U.S. Department of Defense, all services (Navy, Army, Air Force, Marines) to support national security interests via the NOAA/DoD Shared Processing Program.

NESDIS' data is also used by the Government and academic research community, such as Rutgers University, the Universities of Colorado, Miami, Wisconsin; Massachusetts Institute of Technology; the University Corporation for Atmospheric Research; and the Office of Naval Research.

NESDIS' data is also used by many international users, such as meteorological and climate data centers in Great Britain, Germany, India, Switzerland, Canada, and Australia; shipping and fishing interests, and media outlets. The DoD also receives acquired NOAA POES data.

In addition to other operational numerical weather prediction centers, including DoD and international customers, the National Weather Service (NWS) and its National Centers for Environmental Prediction (NCEP) are primary consumers of satellite data. NWS Weather

Forecast Offices (WFOs) use much of the full resolution satellite stream to produce the higher resolution, interactive products required to enhance public safety.

NESDIS has strong partnerships with the NCEP Environmental Modeling Center (EMC), Tropical Prediction Center (TPC), and Climate Prediction Center (CPC). NESDIS and EMC are conducting a number of joint projects to accelerate the use of satellite data in numerical weather prediction. NESDIS and TPC scientists are exploring the optimum utilization of satellite-derived temperatures and winds in hurricane intensity investigations. NESDIS ozone scientists work very closely with CPC scientists responsible for monitoring the stratosphere, and are collaborating with TPC on several tropical storm research projects.

NOAA also established the CoastWatch program, which is a national network of eight regional offices (North Carolina, Michigan, California, Florida, Hawaii, Mississippi, Rhode Island and Alaska) that provide assistance and satellite data to coastal managers, forecasters, and researchers. Each office is located within an appropriate NOAA line office activity in the region (for example, a National Marine Fisheries Laboratory or NWS Regional Office). By virtue of the CoastWatch regional offices being located on-site along the U.S. coast, we have intimate contact with our users and their resource management issues. CoastWatch helps users to become more aware and able to make use of satellite data in local and regional coastal and ocean resource management activities. Many users rely on NOAA's satellite-derived coral bleaching products to support critical natural resource management issues. Other examples of users within NOAA are provided in Appendix 1.

NOAA is constantly looking for ways to improve the efficiencies of its data management functions. Through programs over the past decade such as the National Virtual Data System (NVDS), NOAA was able to manage a 10-fold increase in data archived, a 50-fold increase in the number of users, with just a 40% increase in budget (when adjusted for inflation) and a 30% reduction of federal FTE.

A. <u>Satellite Data Processing and Distribution</u>

The NESDIS Office of Satellite Data Processing and Distribution (OSDPD) manages NOAA's central ground facilities, which process and distribute satellite data and products, derived from multiple sources. These data and products support U.S. Government time-critical mission requirements, such as NWS numerical weather prediction models.

Since the late 1980's, the number of satellite products that NESDIS produces to support NWS and DoD requirements has grown from 40 to 500, and the number of satellites used to create these products have increased from 6 to 18.

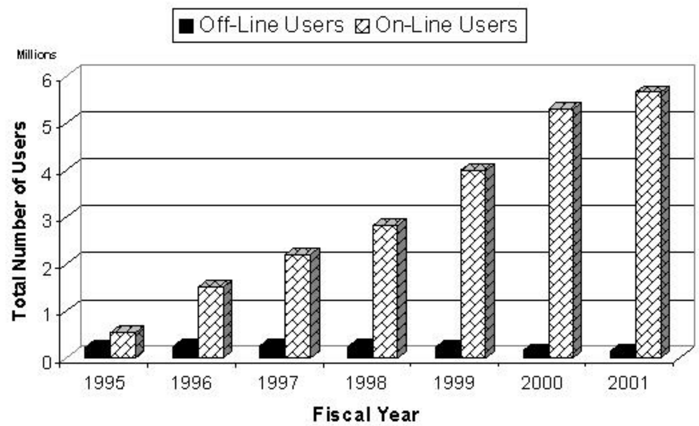


Figure 1: Growth in On-Line Services from NOAA's National Data Centers

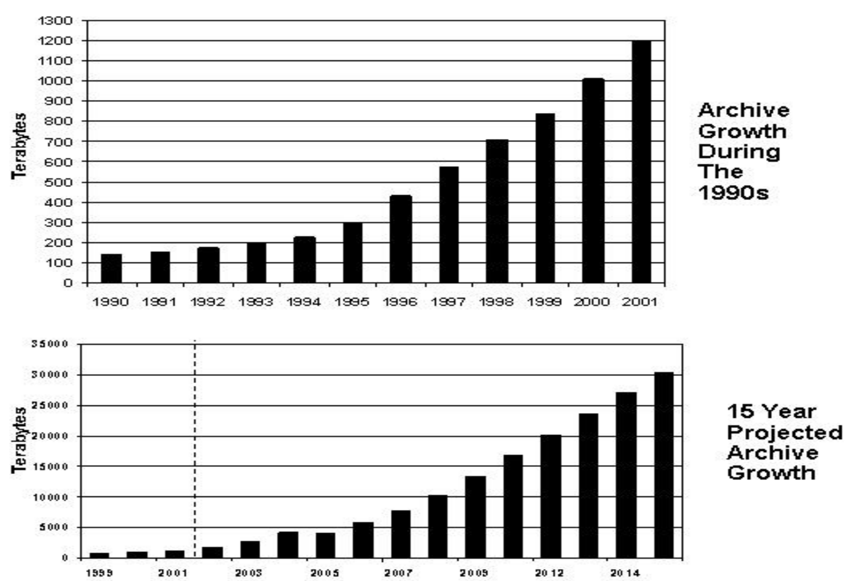


Figure 2: Historical NOAA Archive Growth Dwarfed by Projected Growth

NESDIS has continually focused on maximum exploitation of its available resources; nonetheless, a backlog of **new** satellite products required by NWS, DoD, and other operational users has accumulated. These products and services, which include valuable flood, fire and volcano products, could improve warnings and forecasts if implemented, helping to save lives and property in many parts of the United States. The reliability of NESDIS' satellite data processing operations has also degraded, resulting in instances of delay in delivery of satellite-based information required for severe weather support.

To help correct these problems, the President's FY 2003 President's Budget Request includes four new initiatives to ensure our Nation's ability to best utilize satellite data by addressing the following issues.

- **Reducing the Risk to Continuity of Critical Operations** ($3.05M). This effort provides support to ensure the continuity of critical satellite product processing and distribution capabilities that supply 97% of the data used in NWS numerical weather prediction models.

- **Environmental Algorithm Development for Climate Monitoring & Hazards** ($0.5M). NOAA will use the funds to develop advanced algorithms and methods to handle higher resolution data and techniques to maximize the information content of current and near-future satellite data.

- **Improved Support for Weather and Hazards Products** ($2.0M). These funds will accelerate the deployment of satellite products into operations and provide for their continued support.

- **Joint Center for Satellite Data Assimilation** ($2.6M). These funds will be used to in a partnership program with NASA to more fully utilize satellite data to improve weather forecasts and warnings, and improve accuracy and extend the time range of weather and climate forecasts.

B. NOAA's Plans to Ensure Maximum Use of NPOESS Data

Driven by user requirements, the increasing numbers of satellite missions are placing ever-increasing demands on NOAA's data processing, distribution, archiving and access systems. No previous decade has ever had the magnitude of changes in the volume of data coming into NOAA for processing and archiving that were experienced in the 1990s. However, that explosive growth will be surpassed by what will take place between the year 2000 and 2015. Even as current observing systems continue to provide data, new satellite systems, such as NASA's EOS, the NPOESS Preparatory Program (NPP), and NPOESS itself are, or will be, going into operations. These systems will provide massive amounts of new data that will present major opportunities for NOAA.

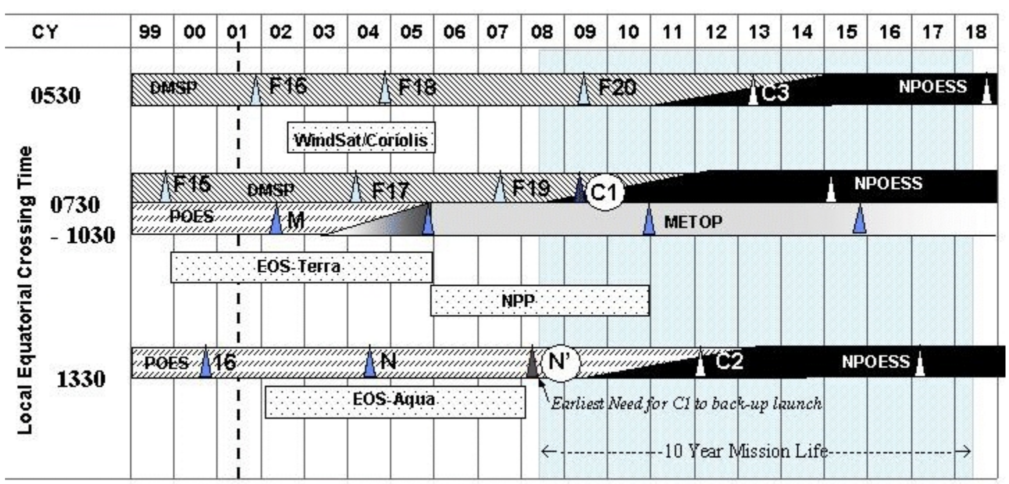
	Parameter	Discipline
★	Atmospheric Vertical Moisture Profile	A C
★	Atmospheric Vertical Temp Profile	A C
★	Imagery	A O T C
★	Sea Surface Temperature	O C
★	Sea Surface Winds	O C
★	Soil Moisture	T
	Aerosol Optical Thickness	A C
	Aerosol Particle Size	A
	Albedo (Surface)	A C
	Auroral Boundary	S
	Auroral Imagery	S
	Cloud Base Height	A
	Cloud Cover/Layers	A C
	Cloud Effective Particle Size	A C
	Cloud Ice Water Path	A C
	Cloud Liquid Water	A C
	Optical Depth/Transmittance	A C
	Cloud Top Height	A C
	Cloud Top Pressure	A C
	Cloud Top Temperature	A C
	Currents	O
	Downward Longwave Radiance (Sfc)	A
	Electric Fields	S
	Electron Density Profile	S
	Fresh Water Ice	O C
	Geomagnetic Field	S
	Ice Surface Temperature	O C
	Energetic Ions	S
	In-situ Plasma Fluctuations	S
	In-situ Plasma Temperature	S

Parameter	Discipline
Insolation	A C
Medium Energy Charged Particles	S
Ionospheric Scintillation	S
Land Surface Temperature	T C
Littoral Sediment Transport	O
Net Heat Flux	O C
Net Short Wave Radiance (TOA)	A O
Neutral Density Profile	S
Neutral Winds	S
Normalized Difference Vegetation Index	T C
Ocean Color/Chlorophyll	O C
Ocean Wave Characteristics	O
Ozone – Total Column/Profile	C
Precipitable Water	A C
Precipitation Type/Rate	A C
Pressure (Surface/Profile	A
Sea Ice Age and Edge Motion	O C
Sea Surface Height/Topography	O C
Snow Cover/Depth	T C
Solar Irradiance	S
Supra-Thermal – Auroral Particles	S
Surface Wind Stress	O C
Suspended Matter	O
Total Auroral Energy Deposition	S
Total Longwave Radiance (TOA)	A C
Total Water Content	A
Turbidity	O
Vegetation Index/Surface Type	T C

A = Atmospheric O = Oceanic T = Terrestrial S = Space C = Climate
★ Environmental Data Records (EDRs) with Key Performance Parameters

Figure 3: Environmental Parameters from NPOESS by Discipline

Satellite Transition Schedule



S/C delivery interval driven by 15 month IAT schedule

Figure 4: Satellite Transition Schedule

1. What does NPOESS funding include?

The tri-agency effort by DoC/NOAA, DoD, and NASA established the NPOESS Integrated Program Office (IPO) to develop and acquire the Nation's future polar-orbiting system. The NPOESS operational suite of instruments will provide continuity to the NOAA POES series and DoD series of polar-orbiting, operational environmental satellite systems incorporating new technologies from NOAA, DoD, and NASA. The first NPOESS satellite is scheduled to be launched in April 2009. Since NPOESS is a joint program, it serves both military and civilian users. It was decided early on that NPOESS funding should include requirements definitions; mission planning; systems definition; systems acquisition; and systems operations and maintenance. These functions include satellite system acquisition and launch, ground systems, command, control and acquisition, and near real-time environmental data record distribution to DoD and NOAA centers. The funding does not include some data management functions such as metadata, archiving, non real-time access, and archive migration to new media. These long-term management functions were determined to be the responsibility of NOAA. NOAA has responded to these NPOESS data archiving challenges, as well as to requirements to provide long-term management of other large data sets such as radar, by defining and planning a data modernization program called the Comprehensive Large Array-data Stewardship System (CLASS), wherein all these data could be handled the same way, and therefore used together in building applications. The FY 2003 budget includes $3.6 million for this purpose. It also has a separate budget line of $3 million to begin archiving EOS data into CLASS. By 2010, the total archived data forecast to be managed will be about 8 petabytes. The resources required for this volume of data, given today's projection of efficiencies, would be in the range of a few tens of millions of dollars per year. Another way to estimate the data management requirements would be approximately 5-10% of the systems budget.

2. Validated Requirements

NOAA will be able to use the data from NPOESS to meet the requirements established in the validated and approved NPOESS Integrated Operational Requirements Document (IORD-II). The improved atmospheric, oceanic, terrestrial, space environmental, and climatic data that will be delivered from the more capable imaging and sounding instruments on NPOESS will be used to improve NOAA's short-term weather warnings and forecast services for protection of life and property, longer-term climate change assessment and prediction, and a variety of other real-time applications. These data will not only be utilized directly in global, regional, and local data assimilation models to support numerical atmospheric and oceanic prediction, but the imagery, soundings, and other NPOESS data will support the generation of over 500 distinct products that will be delivered daily to users in NOAA, DoD, other civilian agencies, and universities. To prepare for these new data, NOAA has begun several efforts to use new data faster, to ameliorate the risks of satellite failures, and to train and educate the community on the applications possible with NPOESS data.

3. Use of Satellite Data in Numerical Models

Much progress has been made in the utilization of satellite data since the first meteorological satellite was launched in 1960. During the 1960s and 1970s, the advances in satellite instruments raced ahead of computing capacity and analysis techniques needed to use these data effectively in weather forecasts. Satellite imagery analysis by local weather forecasters was an immediate success, but the use of quantitative satellite data and products in computerized weather forecasting lagged behind. By the early 1990s, however, very fast computers and sophisticated methods of merging satellite data with numerical forecast models were becoming available.

This enabled, for the first time, direct assimilation of satellite radiance data into U.S. operational weather forecast models, which led to significant improvements in weather forecast accuracy. Data assimilation is the process by which weather observations and a short-term (e.g., 6 hours) forecast of the weather variables are merged to obtain the initial conditions needed to make a numerical weather forecast. The important scientific advances that made direct data assimilation possible were: 1) the development of fast radiative transfer models that allow transformation of weather forecast model variables, such as atmospheric temperature and humidity, into radiance, the quantity measured by weather satellites; and, 2) techniques by which the model variables are modified so that the radiance derived from the models matches the satellite observations. With these advances, the temperature, moisture and wind information inherent within the large volume of satellite data can be used by the models to improve operational weather and climate forecasts. Increased user demand and evolution of satellite capabilities are now imposing a requirement for significant scientific effort to fully exploit the new data.

4. Joint Center for Satellite Data Assimilation

To improve the exploitation of current satellite data and to prepare for quicker use of future data in operational weather forecasts, NASA and NOAA have formed a collaborative Joint Center for Satellite Data Assimilation (JCSDA). It addresses technical issues discussed above, and development of an end-to-end process for the operational utilization of satellite observations. JCSDA will be a center distributed among several centers of expertise. Within NOAA, those centers will include NESDIS, NWS, NCEP, and the Office of Atmospheric Research (OAR). The NASA Data Assimilation Office (DAO) is also a full partner in JCSDA. Each will bring its own area of expertise to the joint effort. This collaboration will make efficient and rapid advances in the use of satellite data in weather forecast models.

JCSDA will promote the development of common weather forecast models for research and operations. Now, each U.S. forecasting center runs its own models, and data assimilation advances made at one center are not easy to transport to the others. Common models will make this process efficient. Components required by data assimilation will be developed for community use. This will include community radiative transfer models, surface emissivity models, and surface physics models. Recent accomplishments of the JCSDA include the operational implementation of QuikSCAT wind and TRMM precipitation data into the NWS/NCEP operational models.

This is the first time NOAA has used data from research satellites controlled by NASA within the operational data stream used by NWS. There have also been major strides in preparation for NASA's Aqua launch this spring so that an accelerated assessment and use of its advanced atmospheric sounding data can occur. These activities are projected to be completed within 10

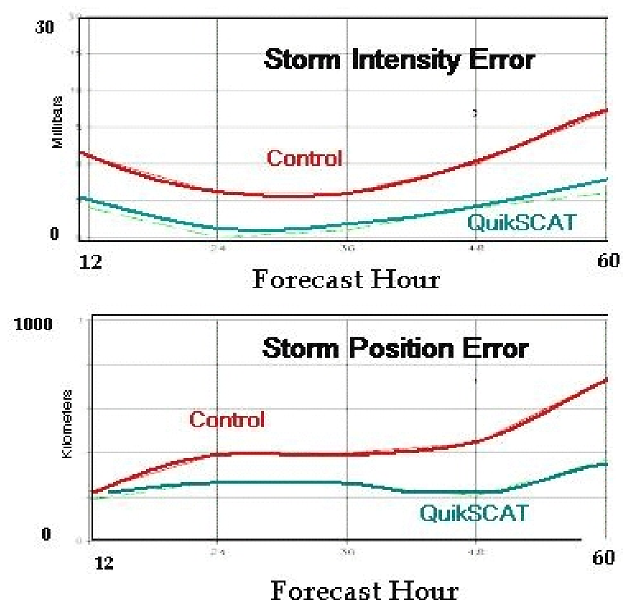


Figure 5: Improvement in Forecasting of Storm Intensity and Storm Position Through Utilization of Ocean Wind Vector Data from QuikSCAT

months, as opposed to the 2 years it has taken in the past to use new satellite data operationally.

Much of the early NPOESS data utilization/demonstration work that NOAA has begun will form the core of the research to operations transition efforts that will be conducted under JCSDA. To support the ongoing JCSDA projects, NOAA, NASA, and IPO invested approximately $2.5 million in FY 2002. Sustained investment in JCSDA will be required to attack existing satellite data assimilation challenges, and to ensure that NPOESS data will be fully utilized when the system becomes operational. DoD has recently been invited to become a partner in JCSDA. Participation of the DoD Operational Processing Centers in JCSDA will help ensure that satellite data processing and assimilation methods developed for NPOESS will be applicable to the

NOAA, Navy, and Air Force processing centers that will be the primary recipients of the NPOESS data.

To assist in this effort, in FY 2003 NOAA has requested an additional $2.6 million for the Joint Center for Satellite Data Assimilation. Using these funds, JCSDA will develop new and powerful mathematical techniques to assimilate current and NPOESS-era satellite data into numerical weather prediction models thus improving the accuracy and extending the time range of weather and climate forecasts.

5. Risk Reduction

The utilization of research satellites by operational agencies is also very important in risk reduction for future operational systems and technology transfer. The groundwork for use of NPOESS data will be laid through a series of systematic risk reduction projects leading from early use of new data from current satellite missions being flown by NASA, to the joint IPO/NASA NPP, which will be launched in 2006, to the first operational NPOESS spacecraft that will be available for launch in 2008 and is expected to be launched in early 2009. To date, NOAA, with support from IPO and NASA (NPP program support) has invested approximately $6.6 million on a series of pre-operational demonstrations and utilization of data from NPOESS-like instruments to ensure that NOAA will be ready to use NPOESS data when the new system becomes operational. Over the next 6 years, NOAA and IPO are planning to directly invest approximately $10 million to continue the development of the processing capabilities for key sensors.

Presently, NOAA is upgrading and enhancing current processing capabilities to begin acquiring and exploiting in near-real time data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Infrared Sounder (AIRS) on the NASA EOS Terra and Aqua missions. The MODIS instrument is very similar to the Visible/Infrared Imager Radiometer Suite (VIIRS), and the AIRS instrument is similar to the Cross-track Infrared Sounder (CrIS) that will be flown on the NPP mission and on the operational NPOESS spacecraft. NOAA efforts with data from these instruments are critical to reduce the risk and gain experience with data handling, processing, storage, and communication of high volume data sets from similar instruments; and to allow the users to gain early, pseudo-operational experience with NPP and NPOESS-like data sets, well before the first operational NPOESS spacecraft is launched.

Similar efforts are being pursued to build the capability to handle and process data from the future Conical-scanning Microwave Imager/Sounder (CMIS) that will be flown on NPOESS to measure, among other parameters, the ocean surface vector wind field. Current efforts at NOAA (and the Navy) address the operational/tactical use of ocean surface vector winds from active scatterometer missions (e.g., SeaWINDS). Beginning in January 2003 with the launch of the joint Navy/IPO/Air Force Coriolis/WindSat mission as risk reduction for the CMIS instrument scheduled to fly on the first operational NPOESS, the NOAA processing capabilities for SeaWINDS will be redirected to processing and utilizing data from the WindSat mission.

Beginning with its launch in 2006, NPP will supply data on atmospheric and sea surface temperatures, humidity soundings, land and ocean biological productivity, and cloud and aerosol properties. NPP will contribute to instrument risk reduction by offering early instrument and system level testing, lessons learned for design modifications in time to ensure NPOESS launch readiness, ground system risk reduction, early user evaluation of NPOESS data products, such as algorithms and instrument verification, and opportunities for instrument calibration.
The IPO will deliver an Integrated Data Processing System (IDPS) to NOAA in 2004 to support the processing of Environmental Data Records (EDRs) from NPP. A prototype NOAA system to further process the NPP data into derived products and real-time applications, distribute the products to users, and archive these data will be developed, evaluated, and perfected with data from the NPP satellite two to three years in advance of the launch of the first operational NPOESS spacecraft.

NOAA is also involved in significant risk reduction for the next generation of advanced geostationary satellites, the GOES-R series. The requirements for the GOES-R series translate into a significantly increased volume of data from the preceding GOES-N series. The impacts of this increase in data must be identified and addressed in the areas of data acquisition, product processing, distribution to real-time users, access and application by users, and retrospective data access and archive. NESDIS has established a user-wide, end-to-end system requirements and implementation process by which impact and development in each of these areas is addressed. Most notably, studies are already underway to consider alternative communication capabilities, which extend from expanded on-board processing to data compression and increased bandwidth. Interface planning documents are currently being developed to identify needs of the NESDIS Operational Data Acquisition, Product Processing and Archive centers, and most importantly, the user agencies, in order to conduct comprehensive and integrated budget and program planning for each system to achieve full readiness by the first GOES-R series launch in 2012.

A major risk reduction program for the future operational GOES-R satellites is the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) project. GIFTS is a tri-agency joint mission with NASA's New Millennium Program (NMP), the U.S. Navy's Office of Naval Research, and NOAA. GIFTS is a sounder with high spatial resolution and very high spectral resolution and will significantly improve the accuracy of temperature and moisture observations and our observations of severe weather. GIFTS, to be launched in the 2005 time frame, will significantly improve our ability to observe, analyze, and predict weather, and will enable scientists and meteorologists to forecast weather with a higher level of accuracy. This capability is especially important in forecasting severe weather, such as thunderstorms and tornadoes. GIFTS will also greatly improve the diagnostic and prediction of tropical storm intensity. NESDIS and NWS will use GIFTS data to improve short-term weather forecasting and to improve hazard monitoring (volcanic ash, wildland fires, and pollutants). However, sufficient resources are needed to ensure that products are delivered to NWS and utilized. GIFTS will offer NOAA early access to advanced sounding products expected from their future GOES-R advanced baseline sounder.

6. Training and Education

A major challenge is training and educating NOAA's large and varied user community on the nature and use of satellite data and products. Improved data utilization is planned by increasing training, user interactions and data access through web sites. Currently users can access data and many of our operational products through the Internet. Examples include imagery from GOES, ocean color from commercial systems, coral reef bleaching, ocean winds and altimetry, atmospheric temperatures, surface temperature, snow cover and ice, aerosols, fires, clouds and vegetation index.

NOAA invests in classroom and computer-based training through the Cooperative Program for Operational Meteorology, Education and Training (COMET) and a joint NESDIS/NWS and Cooperative Institute [Cooperative Institute for Research in the Atmosphere (CIRA) and Cooperative Institute for Meteorological Satellite Studies (CIMSS)] program called Virtual Institute for Satellite Integration Training (VISIT). Attendees of COMET are primarily NWS personnel, although representatives from other agencies (for example, DoD forecasters, university faculty and students) also participate. The VISIT program uses Internet technology to provide distance learning that allows interaction between students and instructors similar to a classroom situation. VISIT provides concurrent instruction to multiple sites. Between April of 1999 and 2001 there were 245 training sessions with a total of 4,585 students. In addition to the VISIT interactive classroom, NESDIS maintains, through its web pages, a Virtual Institute with satellite tutorials, and a wide assortment of case studies, and technical information and documents for users to peruse and use.

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

In addition to classroom efforts, NESDIS scientists participate in traditional workshops, professional conferences and publish in scientific literature.

C. Archiving Challenges from NPOESS and NASA's EOS Satellites

The use of satellite data for climate studies has progressed from being experimental to mandatory. These data sets have proven to be of high value for climate studies. They have been used in regional and global temperature and upper tropospheric humidity trend studies, in studies of the ozone hole, and in studies of clouds and rainfall. These products have, in turn, been used in assessments by the Intergovernmental Panel on Climate Change (IPCC) and in various World

Climate Research Programs (WCRP). Further applications of satellite data to climate studies, particularly for retrieval of column CO_2, are currently under development and appear promising. Several recent National Academy of Science Reports raise concerns about the Nation's ability to monitor climate variations and emphasize the need for a program of long-term, sustained observations of the Earth's changing climate. A major challenge for NOAA and NESDIS will be the development of the science capabilities needed to take on the mission of sustained long-term monitoring of Earth's climate from space. These include:

- Ensuring the required accuracy, continuity, calibration, stability, and documentation that are essential for climate change detection and attribution.

- Transitioning NASA developed technology, in the form of satellite climate instruments, instrument characterization and calibration science, and data processing systems, to NOAA. This will include measurements never made before by NOAA, but crucial for monitoring and understanding climate change.

- Establishing partnerships with the climate user community to update observational requirements, provide feedback on products, and analyze data.

Answering these challenges will take a concerted effort by instrument scientists, climate scientists and computer scientists. There must be extensive collaboration between the research and operational climate communities. Computer scientists, climatologists, and archivists will need to provide a sound and effective means to ensure that all necessary data are preserved and remain accessible in easy-to-use formats. It will also take a long-term commitment to provide resources to enable preservation of the climate archive from the first generation satellite systems of the 1980s and 1990s, through the transition satellite systems of the EOS era, to the second generation of operational systems in the future NPOESS, which will begin operation in 2009.

1. Building the Climate Record

The NPOESS system will have new weather and climate monitoring instruments as well as new instruments for monitoring ozone. A prototype of the NPOESS spacecraft, NPP, will be launched in 2006. A substantial research effort will be needed to insure continuity in the satellite climate record between the current operational system that has been in operation for the last 20 years and NPOESS. The proper time and data sets for this research effort will be provided by NPP, as a bridge to NPOESS. NPP will allow coincident climate observations between the old satellite instruments and the new ones that will begin operation with NPOESS and continue for many years. Construction of a seamless climate record between the current satellites and NPOESS is a very important and difficult challenge.

As a result of this challenge, NESDIS is implementing the concept of scientific stewardship within NESDIS. Scientific stewardship means providing the data and information services to answer the global change scientific questions of highest priority to the nation, both now and in the future.

The NESDIS scientific stewardship program has five goals. These goals are:

- To provide real-time monitoring of climate-scale biases in the global suite of satellite observing systems. Since subtle spatial and temporal biases can create serious problems in future use of the data, we must develop the tracking tools necessary for detection of biases in the climate record. These biases can then be minimized or eliminated through efficient communication and coordination of information related to network performance using both in situ and satellite observations.

- To document Earth system variability and change on global, regional, and local scales. This will be accomplished by building and maintaining a high quality base of data and information and establishing the best possible historical perspective critical to effective analysis and prediction. The creation of long-term, consistent records requires a long-term commitment of resources to accomplish these tasks.

- To provide the necessary algorithms to ensure that understanding of key climate processes can be derived from space-based systems and the combination of space-based and *in situ* systems. The best possible scientific understanding of critical climate and global change issues can only be reached when all opinions and ideas can be explored. Thus, an active program engaging the research community, partnerships with industry, and increased interactions with local and regional governments is envisioned.

- To optimize data and information services in order to make research easier and more effective by ensuring those services are simple, straight forward, direct, and responsive. This will be achieved by establishing end-to-end accountability for establishing long-term, scientifically valid, and consistent records for global change studies. This will ensure that our data and information are available to the maximum amount of users.

- To enable and facilitate future research. This aspect of stewardship involves providing the basic information technology, hardware, telecommunications, and software support to guarantee that data can be safeguarded and communicated both within NOAA and to outside users for generations in the future.

We believe that achieving these goals will result in a long-term archive that is flexible and innovative, that appropriately focuses responsibility on NESDIS for preservation of optimal data character, that provides for open access to the data by the scientific community and the public, and that will rapidly track technological developments.

In order to responsibly perform stewardship of incoming data sets, in FY 2003 NOAA has a new initiative for a Solar X-ray Imager Archive ($0.3M). The Solar X-ray Imager (SXI) represents a new observing capability that will be operational with the activation of GOES-12, currently on standby after successful demonstrations. NOAA will use the SXI archive to derive new products to help reduce the effects of extreme space weather events on telecommunications satellites, and on electrical power services, which cause estimated business losses of $1 billion per year.

2. Comprehensive Large Array-data Stewardship System (CLASS)

There is reason to expect that the information technology advances we have seen in the last ten years will continue in the future. With these advances, NOAA has made significant progress in its ability to archive and provide access, and will continue to leverage these advancing

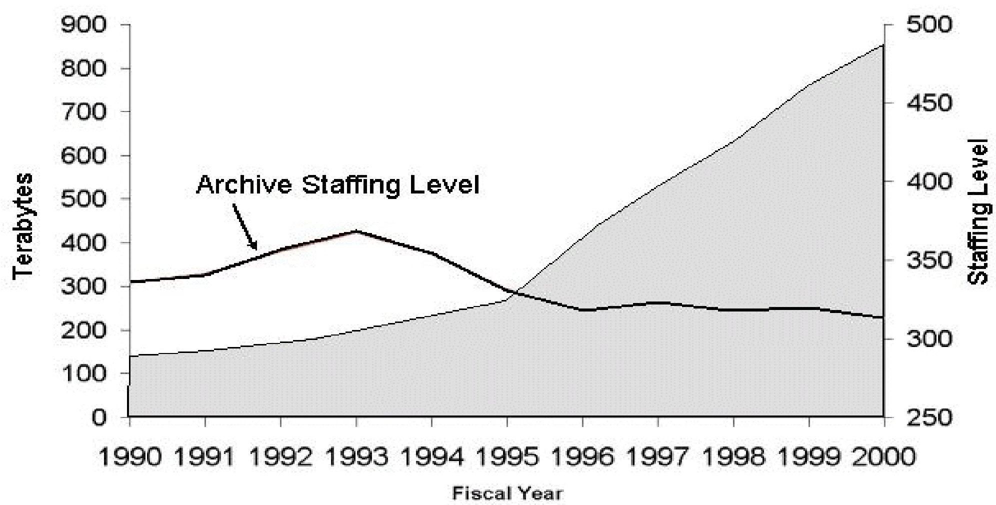


Figure 6: Growth of NOAA National Archives versus Archive Staffing

technologies through effective stewardship of current resources. Management of the increased volume of data can be accomplished only through a rapid expansion in storage capacity, increased communications bandwidth, and automation of the means of data ingest, quality control, and access. The CLASS program will act as the connection in NOAA's effort to meet these challenges and pave the way to accommodate the additional massive data volumes expected over the next several years.

The ability to ensure on-going scientific stewardship for NOAA's environmental data and information will only be possible through extensive enhancement of NOAA's current data ingest,

	Data Sets and Observations	End-to-End Environmental Data Management Functions							
		Planning	Collect or Rescue	Ingest	Metadata & Cataloging	Calibrate & Validate	Store	Access	Migrate
HISTORICAL	In Situ - Centers of Data	✓	x	✓	x	x	●	●	●
	NOAA National Data Centers	✓	✓	✓	✓	✓	✓	●	●
	COOP / USHCN	✓	✓	✓	✓	✓	✓	●	●
	GHCN	✓	✓	✓	✓	●	●	●	●
	CARDS / COADS	✓	✓	✓	✓	●	●	●	●
MODERNIZATION	DMSP	✓	✓	✓	✓	●	●	●	x
	POES	✓	✓	✓	●	●	●	x	x
	ASOS	✓	●	●	●	●	●	x	x
	NEXRAD	✓	●	●	●	x	x	x	x
	GOES	✓	●	●	●	x	x	x	x
FUTURE	New In Situ Land & Ocean Observing Systems	✓	x	x	x	x	x	x	x
	NPP	●	x	x	x	x	x	x	x
	NPOESS	●	x	x	x	x	x	x	x
	EOS	●	x	x	x	x	x	x	x

✓ = Can Do With Current Resources

● = Need Incremental Resources

x = Requires Substantial Additional Resources

Figure 7: Status of NOAA Environmental Data Management

quality assurance, storage, retrieval, access, and migration capabilities. This goal will be met through the development and implementation of a standardized archive management system, which will be integrated with a robust, large-volume, rapid-access storage and retrieval system that is capable of storing the incoming large array environmental data, *in situ* data, and operational products as well as receiving a user's on-line data request, automatically processing the request, and providing the requested data on the most appropriate media. This system will provide standardization in media, interfaces, formats, and processes for the very large datasets produced by satellites and radars. Additionally, the system will facilitate ongoing migration, preservation, and validation to new technology and media. This system is modular in design, built to integrate with automated real-time or near-real-time systems that deliver data. Transaction processing will be implemented to enable an essentially "hands-off" operation and, where appropriate, allow users to pay for data or services through credit card or automated billing.

Placing data on-line for access via the Internet is a high priority in accordance with the Federal government's eGov initiative. Data storage and retrieval systems will continue to be upgraded to support effective and efficient access with special focus on Internet interfaces, emerging telephony technologies, and on-line data that support the objectives of the CLASS concept of operations and ensure that the Nation has access (including Section 508 compliance) to their data and information.

The system will be able to handle the data flow from current satellite-based (e.g., GOES, DMSP, and POES) and ground-based (e.g., NEXRAD) observing systems, and be structured to handle the large increases in data that will come from planned satellite launches, including the METOP, NPOESS, NPP, and some EOS missions.

The target architecture goal will, through life cycle replacements and upgrades, bring the current NOAA National Data Centers under a single archive and access architecture that will be under formal configuration management control. This architecture will eliminate duplication of effort, minimize stand-alone systems, build the infrastructure to accommodate the large array data sets, and reduce the overall operational and system maintenance costs. The foundation system that is being used is the highly successful Satellite Active Archive (SAA). Recognized as a stable, modular, well-built system, the SAA approach provides maximum flexibility while minimizing development work and costs. The heart of the development centers on upgrading communications capabilities, increasing computer storage and power, exploiting commercially available modular hardware and software, and expanding Internet access to the data and information through new or enhanced database management, search, order, browse, and sub-setting techniques.

The FY 2003 NOAA initiative for EOS Data Archive and Access System ($3.0 M) will ensure that NOAA possesses the ability to fully exploit the vast amounts of new NASA EOS satellite data becoming available, process and distribute that data, provide stewardship, and make the data accessible through CLASS to users in the private, research, government, and public sectors.

IV. <u>Conclusion</u>

In conclusion, Mr. Chairman and members of the Subcommittee, I have been pleased to be able to describe the challenges and significant opportunities facing NOAA in optimizing the use of satellite data. We are only scratching the surface on what satellites can do to support the Nation's requirements for environmental data and information. I have described the numerous initiatives underway, and those requested in FY 2003 by the Administration. These initiatives allow us to do the most that we can to continue to provide operational products and services to our current users, to create some of the most important new products requested, and to effectively plan for our future using an end-to-end approach. A key element to our strategy is partnering with other agencies, such as NASA and DoD, international partners such as Europe and Japan, and academia. These partnerships have proven to be wise investments for NOAA and the Nation. We have also greatly appreciated the support and interest expressed by this Subcommittee.

Mr. Chairman and Subcommittee members, this concludes my testimony. I would be happy to answer any questions.

Appendix 1

Examples of NOAA-wide Utilization of Satellite Data

National Weather Service (NWS)

Much of the full resolution satellite stream is used to produce the higher resolution, interactive products required by NWS Weather Forecast Offices (WFOs) to enhance public safety. The number of satellite products that NESDIS produces to support NWS, Department of Defense, and other users' requirements has grown since the 1980s from 40 to 500. For numerical weather prediction modeling applications, data derived from the POES, GOES, and Japan and Europe's geostationary satellites, are sent to the NWS National Centers for Environmental Prediction (NCEP) where these data are ingested into NWP models as radiance information.

Significant improvements in weather forecast accuracy came in the last half of the 1990s when, for the first time, satellite sounder radiance data were directly assimilated into U.S. operational weather forecast models. Over the period 1990-2010, there will be a five orders of magnitude increase of satellite data with potential for use in weather forecast models. Even after the data are thinned by an "intelligent process" to select the best observations, balance inputs, and minimize correlation errors, NOAA satellites provide 97% of the observational data assimilated into NWS NWP models.

Some of the satellite data not currently used by NCEP await scientific advances to allow us to properly model all physical processes that affect numerical predictions. As we improve our understanding of the complex geophysical processes through improved science and model techniques, the NCEP will more efficiently exploit the satellite data currently received and planned for future use.

Office of Oceanic and Atmospheric Research (OAR)

NOAA's OAR is a co-investigator with NESDIS in a number of GOES model impact studies and field collaborations. Model impacts include studies with high spectral resolution infrared sounders and Global Positioning Satellite (GPS) meteorological profilers. Field collaborations include the Nauru Island ocean and atmospheric experiment. In addition, a scientist from the National Severe Storms Laboratory is stationed half time at the University of Oklahoma's Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), where joint studies on using GOES Imager and Sounder data in field nowcasting and forecasting are being pursued.

National Marine Fisheries Service (NMFS)

NMFS is a key partner in our effort to apply remote sensing technologies to fisheries management. NMFS is host to four of the eight CoastWatch regional offices. NMFS also makes use of NOAA satellite-based data collection to track the migration and movement of fish such as great white sharks, bluefin tuna, and marlins. These satellite data are extremely valuable in modeling fish behavior and in determining stock limits. NMFS also uses satellite-derived data collection system to monitor fishing vessel movement and activity in specific fisheries. The fishery industry benefits from the satellite-assisted search and rescue program (COSPAS/SARSAT) which aids U.S. Coast Guard to rescue mariners in distress.

National Ocean Service (NOS)

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

Office of Marine and Aviation Operations (OMAO)

OMAO benefits from a number of satellite-derived marine and aviation products and services developed using NOAA satellite data and data collection systems.