II. Spectrum of NOAA Environmental Data Services

A. Ecosystem Management

A New Era

NOAA has long played a leading role in marine, coastal, and estuarine ecosystem management. Explicitly through amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and implicitly in other stewardship programs, NOAA develops stewardship, research, monitoring, and coastal management programs based upon coastal and near-shore ecosystems and their plethora of associated habitats. In addition, NOAA is mandated to provide stewardship and management of coastal biological resources based upon the best available scientific information. In its purest form, scientific information derives from research studies and monitoring programs that use data at their core. Therefore, data management forms the foundation upon which accurate translation and dissemination of this information must be built. And, one of the foundation blocks is metadata or "data about data" that describe the content, quality, condition, and other characteristics of data. With new and rapidly developing capabilities to provide online access to standardized metadata, detailed data search, raw data, and geographic information system (GIS) mapping utilities, NOAA now enters a new era of ecosystem stewardship and management. In the near future, it will be possible for researchers, federal and state agencies, coastal decision-makers, and the public to access the coastal data record with a comprehensiveness and ease that was not available a decade ago. This access will provide tremendous benefit to society by maximizing the utility of the existing data record, while clarifying where the focus should be for future coastal ecosystem research and monitoring programs.

NOAA's Stewardship History

Since its creation through President Richard M. Nixon's Reorganization Plan Number 4 of July 9, 1970, NOAA has been the primary agency responsible for stewardship of the Nation's coastal and marine natural resources. Of particular importance to that responsibility were the following: incorporation into NOAA of the National Marine Fisheries Service (NMFS), which formerly had been in the Bureau of Commercial Fisheries within the U.S. Fish and Wildlife Service; passage of the Coastal Zone Management Act of 1972 (CZMA) (now entitled The Coastal Zone Protection Act of 1996); passage of the National Marine Sanctuaries Act of 1972; and passage of the Magnuson Fishery Conservation and Management Act of 1976 (now the Magnuson-Stevens Act or MSFCMA). In addition, numerous important environmental laws fall within the scope of NOAA, NMFS, and National Ocean Service (NOS) programs, including but not limited to: the Endangered Species Act, Marine Mammal Protection Act, Clean Water Act, National Environmental Policy Act, and Oil Pollution Act and the Fish and Wildlife Coordination Act. Through the CZMA and the Marine Protection Research and Sanctuaries Act, NOAA has long been a leader in coastal and estuarine ecosystem management. More recently, this role has expanded explicitly to NOAA fishery management through requirements that NMFS apply the ecosystem approach to fishery research, monitoring, and management programs. The U.S. Environmental Protection Agency plays a significant role for endangered species activity in fresh water. The U.S. Fish and Wildlife Service coordinates with NMFS on marine species.

Under CZMA, each coastal and Great Lakes state with a federally approved (NOAA) coastal zone management plan (CZMP) is eligible for substantial financial assistance to implement the plan, and is given consistency review of federal permits and activities that affect the state's coastal zone. Through its CZMP, a state may determine coastal zone boundaries, define and manage land and water uses within the coastal zone, designate areas and/or habitats of particular concern, establish a planning process for energy facility development, establish a planning process to control and decrease shoreline erosion, and facilitate effective coordination and consultation between regional, state, and local agencies. Activities within the coastal zone may be subject to state CZMP permits, regulations, or other CZMP-enforceable policies. In addition, permits from other federal agencies that may affect a state's coastal zone usually may be granted only following that state's determination that the permit is consistent with the provisions of its CZMP. This gives coastal states substantial ability to influence federal activities through their coastal zones. Consequently, through CZMA, NOAA has become directly involved in the coastal ecosystem management of all but one coastal and Great Lakes state.

Another important provision of CZMA is the National Estuarine Research Reserve System (NERRS). The NERRS is designed to address the long-term goals of CZMA by conserving regionally characteristic estuaries around the Nation as ecological reference sites, and by improving coastal management through application of research and monitoring programs to state coastal zone management programs. Each of the 25 research reserves nationwide also conducts innovative public education and outreach programs that are designed to enhance public perception of coastal and estuarine resources. Subject to NOAA approval of a reserve management plan, each NERR is run by its host state, and is urged to work in close cooperation with NOAA and other reserves in the system. Close cooperation among the research reserves make the NERRS a valuable national coastal knowledge base, with a large potential for providing system-wide standardized research and monitoring data.

Similar to NERRS, the National Marine Sanctuaries Program (NMSP) was implemented under the Marine Protection, Research and Sanctuaries Act of 1972 to protect and manage areas of the marine environment with distinctive national significance due to their conservation, recreational, ecological, historical, research, educational, or aesthetic qualities. Because of their emphasis upon stewardship, research, and monitoring, the 11 National Marine Sanctuaries also operate from an ecosystem management perspective, coordinate among themselves, and exhibit great potential for cross-cutting research and monitoring data with other NOAA programs.

Mandated Requirements

Passage of the Sustainable Fisheries Act of 1996, which amended the MSFCMA, set forth a number of new requirements for fishery management, including increases in the detail and number of stock assessments that are to be conducted, consideration of ecosystem management in the management planning process, and determination of essential fish habitat for current and future federally managed species. These requirements significantly add to the data management needs imposed by the Act. For example, essential fish habitat delineation and critical habitat delineation (required under the Endangered Species Act and the Marine Mammal Protection Act) require data sets that cross-cut numerous fields. Fishery, oceanographic, and coastal science information are involved. These include foundation data layers such as bathymetry, temperature, salinity, hydrology, and other physical, chemical, and geological variables; habitat data layers such as emergent and submerged aquatic vegetation, sediment-type, bottom structure, floating algae such as *Sargassum spp.*, intermittently flooded marsh vegetation, and other estuarine ecological features such as bays, bayous (or sloughs in some regions), and coastal forests; and life history data layers for both species of concern and other species that interact with these species (including humans). NOAA data management needs are similar for other important coastal issues such as marine alien species, habitat restoration, coastal change, ocean and coastal observing systems, harmful algal bloom observing systems, hypoxia, coastal risk, and homeland security related to ports.

Current Ecosystem Data Management Activities

Much of current ecosystem data management within NOAA is composed of separate efforts located at the regional and national levels and among line offices. Currently, NOAA is developing several initiatives to integrate data management efforts for data located both within NOAA and throughout the research and management community. Included with this are: standardized metadata tools, enterprise GIS mapping capabilities, and data portals and middleware that allow remote access to data in standardized formats.

For example, NOAA employs a regional approach for fishery resources management in response to its mandate under the MSFCMA. Eight Fishery Management Councils, all serving separate regions of the United States, often require a unique mix of data to meet their needs. The Councils, composed of resource managers and regional members appointed by the Secretary of Commerce, are major clients of NOAA. NOAA must anticipate the Councils' needs for data and data syntheses that provide the background for management decisions and further direction for research, or to advocate for clear research direction.

While the Management Councils make recommendations on management regimes and regulatory measures, NMFS implements regulations and issues permits. Supporting these activities requires sophisticated data management and infrastructure. For example, there are currently about 24,000 permits managed by the Atlantic Tuna Fisheries Permit System, 14,000 permits issued by the Southeast Regional Office, and more than 15,000 permits issued by the Alaska Regional Office. When other smaller permit programs are counted, the total number of permits exceeds 90,000. This permitting system requires integrated data management, and continually improving metadata and access capabilities.

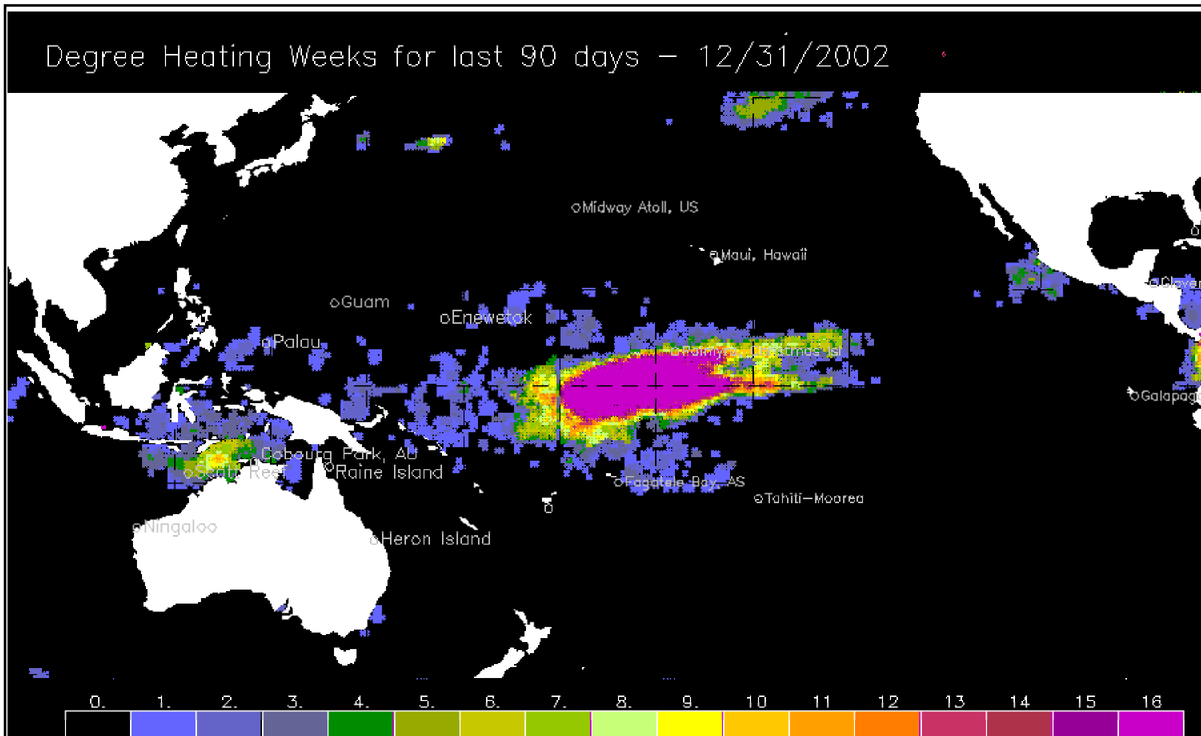
Other important information required by both the Councils and NMFS are socio-economic and socio-cultural data inputs. As a reflection of the size and scope of the task at hand, a recent NOAA workshop[10] estimated that there are up to 3,000 communities and ports in the United States and its territories involved in some aspect of fishing or fish processing. Furthermore, this workshop made an approximate estimation on the distribution of these communities and ports: Northeast, 500-600; Mid-Atlantic, 400; South Atlantic, 400; Gulf, 500-600; Caribbean, 120; Alaska, 350; Northwest, 50; Southwest, 100; Hawaii and Western Pacific, 94. This distribution represents a mix of all the kinds of communities engaged in fishing, both large and small. These communities benefit from the decisions made on resources by the Councils. In addition to marine resources data collection, recent laws in support of fisheries management require NOAA to collect socio-cultural information on all these communities. Standard databases are being created that will enable systematic access of community-based data, both within regions and across regions to build accurate, scientifically based analyses of the impact of fishery management actions.

NMFS maintains large ecosystem and fisheries management data holdings in relational databases at data centers located in Silver Spring, Maryland, and at regional offices in the northeast, southeast, southwest, northwest and Alaska. Data are managed by regional database administrators through the regional science centers and offices, and are coordinated by the NMFS headquarters offices of Science and Technology and the Chief Information Officer.

Marine Habitat Data Management

In support of its national monitoring mandates and the research requirements of the Marine Protection Research and Sanctuary Act and the CZMA, NOS maintains publicly available data sets on coastal quality, distributions of chemical contamination, sediment toxicity, benthic community structures, living marine resources by life stage, habitat types, species habitat preferences, harmful algal blooms and marine and coastal reserve boundary designations. The success in applying this information to a management problem depends upon the spatial resolution. Quite often, the available data are sufficient for characterizing environments generally, but are insufficient for immediate and site-specific needs. Such data allow the managers or researchers to see what is known, but also to find that more data are required. The NERRS and NMSP maintain monitoring programs in specific areas and fine spatial resolution data are publicly available. The data for all reserves are available at NOAA's National Oceanographic Data Center (NODC), while that for the sanctuaries must be accessed through Internet sites maintained by each sanctuary.

At a larger scale, NOAA Marine Environmental and Fisheries Laboratories provide overlays of atmospheric and oceanographic data with time and location-coordinated biological collections to provide a working complex for understanding seasonal and longer climatic cycles and their impacts upon ecosystems. Knowledge of larger-scale environmental forces upon fluctuations in fishery stocks, protected species, and coastal ecosystems provides additional parameters that must be incorporated into management schemes.



Coral reefs compose a large and integral part of the coastal ocean, supporting a variety of sea life and providing resources of significant economic importance. NOAA scientists are using satellite data to monitor the long-term effects of heat stresses on several coral reefs throughout the world. A Degree Heating Week (DHW) indicates the accumulated stress experienced by coral reefs. If the current temperature of the reef site exceeds the maximum expected summertime temperature by one degree Celsius (C), then the site receives a rating of 1 DHW. If the current temperature is two degrees C above the maximum expected temperature or one degree above for a period of two weeks, the rating is 2 DHWs, and so on.

Developing Programs and Future Needs

NOAA overall data management needs are extensive and cut across many disciplines. Numerous ongoing and developing programs in NMFS, NOS, and the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) exemplify major steps NOAA continues to take to develop integrated programs for data management of ecosystem issues. Ongoing programs include the Coral Reef Information System (CoRIS), developed through a partnership between NMFS and NOAA's National Coastal Data Development Center (NCDDC); the national Harmful Algal Blooms Observing System (HABSOS); and the Integrated, sustained Ocean Observing System being developed in response to a Congressional request to the National Oceanographic Partnership Program.

The commercial fishing community in the Northwest is a direct user of the highly successful ATLAS program. ATLAS enables the at-sea observers to enter catch data into an authorized system via the Internet as required by the Northwest Fishery Management Council for several managed species. Not only does the system allow for vessel owners to manage more efficiently the way in which their boats fish target species, it also allows them to reduce their take of non-target species (termed bycatch).

Important developing programs that utilize improved data access, data management, and accompanying GIS mapping include:

- The national ecosystem data management program that focuses data access and management activities on habitat delineation for essential fish habitat and protected species;
- A data management, access, and GIS mapping and analysis initiative on-going in the Gulf of Mexico region and preliminary to national expansion for use in definition and management of essential fish habitat and protected species habitat (cross-cutting program partnership between NCDDC and NMFS);
- A marine alien species pilot project in Hawaii that will be expanded nationally to provide data management for invasive species programs;
- Estuarine habitat restoration science and management programs; and,
- Data management pertaining to large marine ecosystems.

With improved computer technology allowing for online access to data, the advent of integrative and standardized metadata development and management, and development of highly useful GIS mapping and analytical tools, all of these programs will grow and evolve in the coming years to encompass an ever-widening array of data access, products, and information offerings.

NOAA environmental data requirements for ecosystem management are based upon dozens of stewardship and management mandates that span the Nation's coasts from the coastal zone and related watersheds through the 200-nautical mile U.S. Exclusive Economic Zone. These mandates address ecosystems and associated habitats for managed fishery species, listed and protected species, estuarine and marine ecosystems, sea level rise, coastal change, coastal risk, and even homeland security. Research and monitoring programs resulting from these mandates generate vast data sets that require sophisticated management capabilities. With online metadata, data access, and GIS mapping tools, NOAA will have the capability to provide access to the coastal data record to a degree that had heretofore been impossible. However, much still needs to be done to standardize data sets and metadata, to manage research, monitoring, and data management programs in a coordinated way, and to improve overall consolidation of data throughout the NOAA line offices. As NOAA incorporates an ecosystem-based model into fisheries and coastal zone management, efficient access to and effective use of habitat data will become critical components of planning and management. These data are integral to important activities such as defining the geographic extent of ecosystems, characterizing food webs and the associated habitats, describing the habitat needs of all managed species in food webs, developing indices of ecosystem health, and long-term monitoring of the chemical, physical, and biological characteristics of marine ecosystems.

The relatively recent push toward ecosystem-based approaches and the increasing demand for information to allow finer scales of resource management spatially (geographic distribution) and temporally (seasonally, monthly, and even weekly) calls for diverse data needs. In many cases, these needs are immediate, as coastal resource managers attempt to do their jobs on a day-to-day basis. However the task of providing accurate, timely, accessible data remains problematic, as much of the available coastal data record is scattered among various entities within local, state, and federal agencies; public and private regional organizations; universities; and the private sector, including industry and other interest groups.

Future NOAA Ecosystem Management Strategy, Goals, and Challenges

Current data management efforts recognize similarities and differences among NOAA mandates, programs, and products. Within NMFS, several habitat pilot projects are being coordinated to develop a single architecture and nomenclature that will eventually be applied throughout the national habitat programs, including protection, habitat restoration, coral reef restoration, and other areas. Environmental data sets will be useful across programs working on protected resources, habitat, and fisheries; especially as the agency incorporates ecosystem-based approaches, regional applications, and other resource management mandates. Despite such planned and structured efforts to standardize the integration of data sets, some projects will still require special planning, involve different variables, and employ unique qualitative data models that may not be supported by existing databases. Management of NOAA environmental programs requiring cross-program cooperation to ensure design of an environmental data management system that is based upon national standard operating procedures, while maintaining the flexibility needed for individual programs.

NOAA is working to provide more innovative access to the entire coastal environmental data record and continually evaluates its needs for both environmental data and management of these data holdings. Through several interdisciplinary cross-cutting efforts among line offices, protocols are being developed that promise to enhance efficiency and consistency in data management, access, and GIS mapping. Traditional metrics, such as wetland acreage, pounds harvested, and oceanographic parameters, will be integrated with other data layers to give coastal researchers and decision-makers a measurable and consistently improving capability to access and use the coastal data record to address existing and emerging issues of local, national, and international importance.

New tools will be applied to NOAA data holdings to expand access to distributed data sets used to improve observing/monitoring protocols, understand relationships, and develop predictive tools. NOAA environmental and data management programs will include an inventory of both short- and long-term time series, review mechanisms for data set quality assurance/quality control, standardized metadata development and management, assimilation of cross-cutting baseline databases, and design research efforts to integrate comprehensive data sets. NOAA continues to strive for enhanced temporal and spatial scale environmental influences that overlay seasonal and site-specific biological complexes.

NOAA continues to aggressively address and pursue:

- Comprehensive inventories of internal and external data holdings to identify knowledge gaps;
- Research programs to fill vital gaps, including new procedures to ensure that data collections are spatially defined;
- Creating standard databases that will enable systematic access of community based data, both within regions and across regions to build accurate, scientifically based analyses of fishery management actions and their subsequent impacts to the environment;
- Standard protocols for systems architecture, project design, and related reports;
- Improved technology and training so that employees are prepared to employ the most effective available software and hardware to address management issues; and
- Partnerships to benefit from external data holdings.

Many management mandates require a long-term assessment because natural variability and the influence of other factors are only evident over the span of decades or longer. Thus, NOAA environmental programs will locate data sets and work with data providers to rescue data on deteriorating media, to digitize data, to develop standardized and federally compliant metadata, and to develop appropriate access to the data for use in research, monitoring, and management programs. NOAA will endeavor to compile the entire coastal data record, and make it available for use in addressing current and future resource management and research issues. By achieving this ambitious goal, the agency will have, in effect, "activated" the long-term coastal data record by making available to resource managers and researchers all the coastal data that has been collected over the last two centuries.

In addition, despite the intrinsic value of historical data, (e.g., estimating historic population size, reconstructing habitat maps, estimating the pristine state of coastal ecosystems, developing long-term time-lines), many databases lack a spatial component and consistent sampling methods, so that linkages to other data sets are difficult. Developing standards for linking data sets thus becomes an obvious priority. Similarly, standards of quality assurance will be implemented and maintained to provide data that meet critical definitions of scientific integrity. Finally, as the data become increasingly accessible, controls must be implemented and maintained to mitigate the potential for misuse of these data.

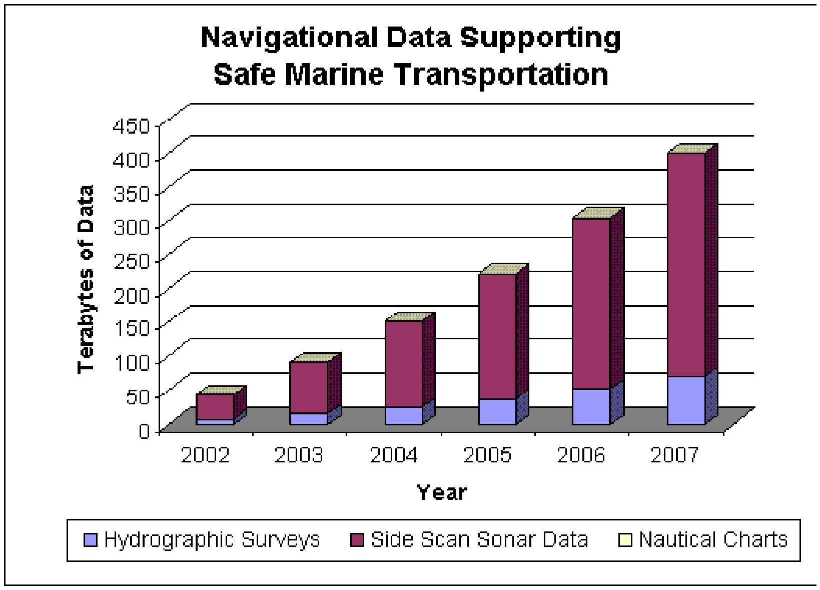
B. Commerce and Transportation

NOAA's Critical Data and Information for Sea, Land, and Air Commerce

NOAA provides critical information, products, and services essential to the safe and efficient transport of goods and people at sea, in the air, and on land. A wide array of data are acquired, ranging from periodic to continuous, ocean to land and the atmosphere, and utilizing both fixed and mobile platforms. Appropriate technology is needed to maximize both the quality and the efficiency with which it manages its data to ensure data are accurate, reliable, and readily accessible to meet the stringent demands of the transportation sector.

Marine Commerce and Transportation: History and NOAA's Vital Role

Maritime trade is vital to the Nation's economic prosperity. Today, more than 95 percent of non-North American Free Trade Agreement United States foreign trade moves by sea. Two-thirds of everything purchased by American consumers arrives by ship, about 2.4 billion tons of cargo annually, and this trade is conservatively expected to double by 2020.[11] Billions of barrels of oil and millions of tons of coal, as well as a steadily increasing supply of liquified natural gas, are shipped through the Nation's ports every year to consumers across the Nation and around the world. Vessels have also grown in size dramatically; over the last 50 years, the length, width, and draft of commercial vessels have doubled, posing significant safety concerns. In addition, the U.S. coastal recreation and tourism industry with over 17 million recreational boats has an annual economic value of over $30 billion to the country.[12]

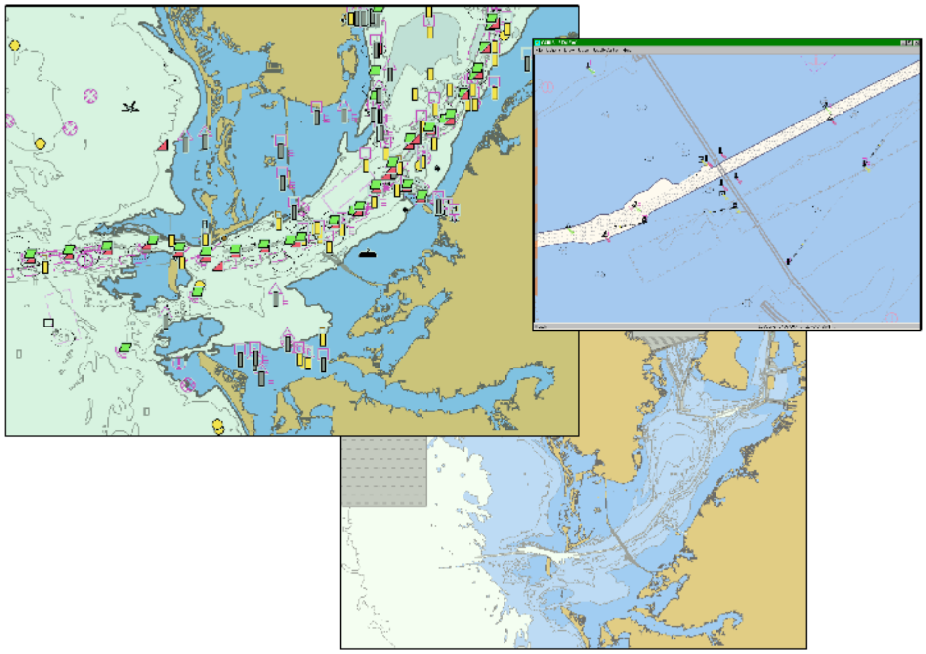


NOAA's mandated role is to assure the safe passage of vessels carrying these energy and commercial goods, passengers, and recreational boaters by providing accurate and timely navigational data and information. This critical information is acquired and distributed to mariners navigating our waters and to key players active in port and harbor development, from the ice covered waters in Alaska to the small estuaries along our coasts. The use of NOAA's data increases commercial efficiency, safety, and environmental responsibility in the Nation's ports and on the waterways.

Example of NOAA's shoreline mapping activity for New Orleans, Louisiana. The image on the left is an aerial photograph. The image on right displays the shoreline derived from the photograph that is used on NOAA's nautical charts. Stereo photogrammetry with tide-coordinated, GPS-positioned aerial photography is used by NOAA to accurately delineate the shoreline.

NOAA's Navigational Data: Nautical Charts

NOAA's Nautical Charting Program is responsible for providing up-to-date charting information to support safe navigation in the waters of the United States and its territories. A nautical chart enables the mariner to fix positions and plot an efficient course while avoiding rocks, wrecks, shoals, reefs, tide rips, and other known hazards. Nautical charts and their source data, such as hydrographic surveys and supporting documentation, are legal documents that are often referenced in court cases dealing with vessel groundings or other mishaps at sea. As such, all chart editions, hydrographic surveys, and documents must be preserved, archived, and made readily retrievable.



NOAA Electronic Navigational Chart of Tampa Bay – displayed at three different scales.

NOAA produces and maintains a suite of approximately 1,000 nautical charts in paper and raster formats. A raster chart is an electronic "picture" of the paper chart that is not interactive. NOAA is in the process of building a complementary database of Electronic Navigational Charts (ENC's) in vector format. A vector format allows the user to interact with the chart via software programs in many ways, such as choosing depths or objects and getting detailed descriptions of them, getting a position of a navigational aid, displaying dredged channel depths, or setting safety zones based upon depth of water. It brings together many in-house and external data sources into a single, compiled, geographically referenced product that is provided in a standardized international format.

With ENC's, mariners have taken a major step into the interactive (GIS) world. The NOAA ENC data product has the potential to be a coherent, up-to-date, best-scale representation of the coastal United States in vector form. The database being built by NOAA to support ENC production will be used to modernize all of NOAA's navigational products. It is also being designed for direct access by non-navigational users who want to access specific data themes in the coastal U.S. and to download data in the format of their choice. This database is an important part of the U.S. geospatial data holdings. It will represent the only geospatial database of coastal information (shoreline, bathymetry, navigational features, etc.) that is kept up-to-date for changes to these features.

Building a system to maintain this database and loading it with the best available navigational data has been a difficult and resource-intensive task. Extensive use of contractors has helped with the loading process. Software companies have advanced the state-of-the-art in geospatial databases and product generation technology to the point that a system capable of meeting all requirements is now feasible. The next steps will be accomplished as a partnership between industry and NOAA. However, such a partnership will put an even greater demand on our resources. The challenge ahead is to build a system that will streamline production and ultimately improve productivity and product quality while continuing to produce the products upon which mariners, boaters, and other users depend.

NOAA's Ice Coverage Charts and Analyses

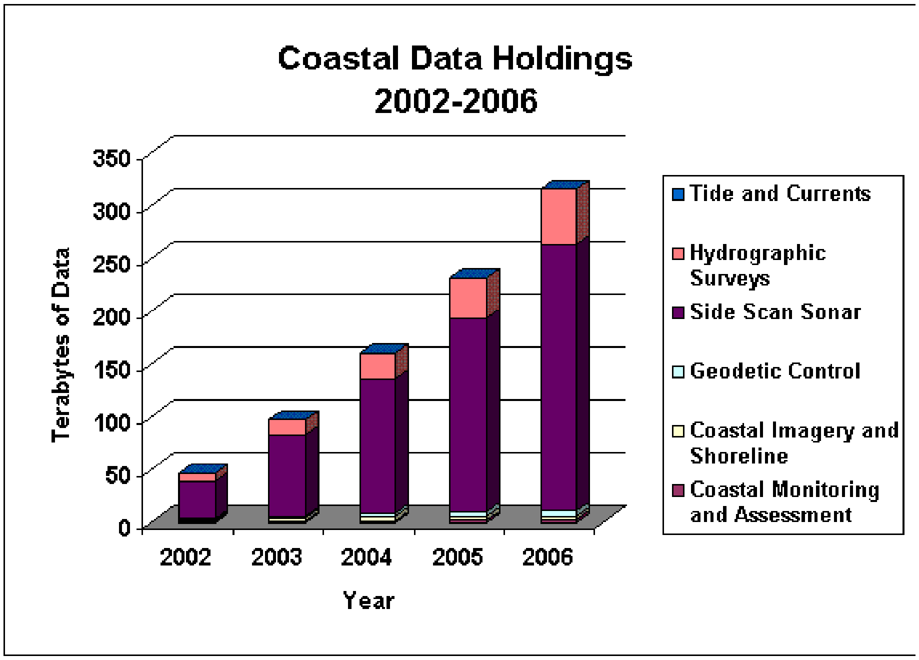
Sea and lake ice pose a serious hazard to shipping and other maritime activities in the Alaskan region, Great Lakes, and polar regions. Accurate ice analyses and forecasts are essential for ensuring safety of navigation and protection of life at sea year-round in Alaska and for the 6-month winter season in the

Great Lakes. Economic benefits include the prevention of marine vessel damage or loss, as well as significant fuel savings for the marine transportation industry when vessels are able to take the most direct path through the ice.

The National Ice Center, a partnership between NOAA, the U.S. Navy, and the U.S. Coast Guard, is an operational sea ice analysis and forecasting center that produces ice products designed to support the safety of U.S. shipping and marine transportation interests in the Great Lakes and Alaskan regions. In Alaska, the commercial fishing industry uses ice information on a daily basis to protect and ensure the safety of fishing vessels operating near and within the Bering Sea ice pack. The oil industry in Alaska is also critically dependent upon ice data during the annual maritime re-supply of Prudhoe Bay. In addition, the U.S. Coast Guard routinely uses detailed ice analyses to escort transport vessels and commercial carriers transiting the ice-covered Great Lakes. Mineral, natural gas, and petroleum extraction are performed adjacent to or in ice-covered waters in both the Northern and Southern hemispheres. Eco-tourism in the form of skiing explorers and cruise ships has become increasingly popular in both the Northern and Southern hemispheres.

The National Ice Center has produced weekly charts depicting U.S. territorial, Arctic, and Antarctic sea ice conditions since 1972. These analyses are produced using all available *in-situ* and remotely sensed data and prediction models. The National Ice Center operates on a 24x7 basis.

Recently, both observational and modeling studies have shown that sea ice concentration, thickness, and extent are important indicators of the state of the climate system. Due to intense interest in these data by the scientific community, the National Ice Center, in cooperation with the U.S./Russia Environmental Working Group of the U.S.-Russian Bi-national Commission on Economic and Technological Cooperation, released 1972-1994 Arctic ice analyses in digital format in October 2000. However, the format of this product suite cannot be transformed easily into one compatible with the GIS environment or scientific analysis software.

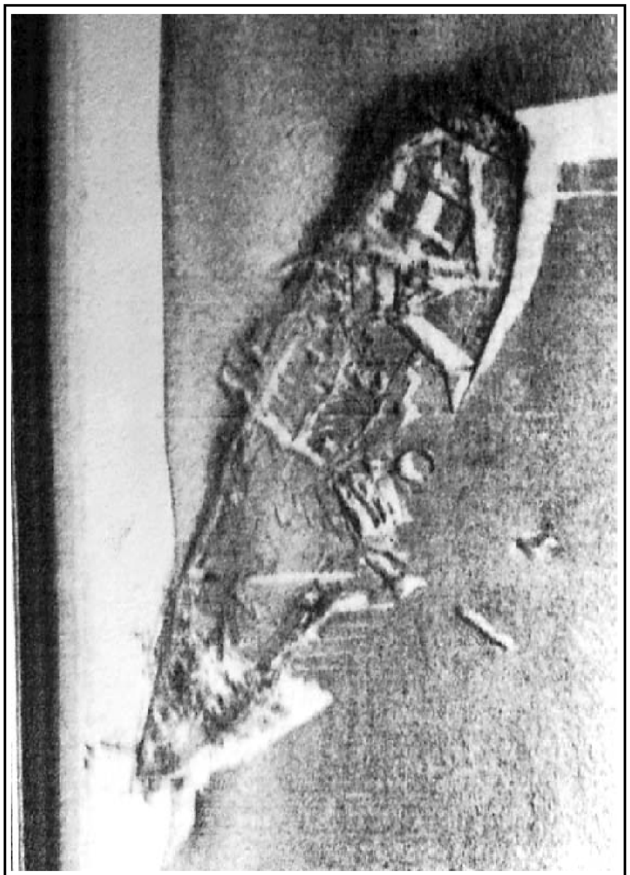


NOAA also recently released a 1973-2000 compendium of ice charts of the Great Lakes region. This data set has already proven invaluable for route and mission planning for safety of navigation in the region, as well as for scientific studies of change in the ice cover. However, resource levels at this time do not permit the addition of weekly lake ice charts produced after 2000. In addition to the weekly lake ice charts, complete, semi-automated, weekly quality-controlled, hemispheric coverages need to be developed with the data disseminated in user-friendly formats, and archived for future analysis.

NOAA's Hydrographic Surveys

NOAA and its predecessor agencies have been performing hydrographic surveys of U.S. coastal waters for more than 160 years. Hydrographic surveys measure and define the configuration of the sea floor because the precise locations of depths significant to surface navigation are critical on nautical chart displays. Hydrographic survey data also support port and harbor maintenance (dredging), coastal engineering (beach erosion and replenishment studies), coastal zone management, and offshore resource development activities. NOAA has an inventory of approximately 11,000 hydrographic surveys, of which only 5,100 are in digital form. The remainder are on paper or linen. These original documents, regardless of age, continue to be used for historical research and change analyses. It is critical that these surveys be digitized to support the development of ENC's and to supply information for GIS applications for users such as coastal zone managers.

With the many recent advances in technology, significantly larger data sets are being acquired through hydrographic surveying. Currently, cartographers are coping with large-volume, multibeam sonar data sets of up to 15 megabytes of data per day per vessel. Data handling, processing, quality control, and significant depth sounding selection issues are of major concern. Also, investigation is underway to determine the best methods to distribute and archive the digital side scan sonar and bottom backscatter data sets acquired in support of nautical charting efforts [up to 600 gigabytes (GB) of data per day per vessel], which are of interest to the Department of Defense, the many entities studying fisheries, geologists, and a myriad of other users.



Side scan sonar picture of the Vineyard Lightship which sunk in 1944 during a storm. Side scan sonar is an invaluable tool for identifying potential hazards on the seafloor. Digital side scan sonars have been in use by NOAA for hydrographic surveying since 1997. As of 2002, 36 terabytes of data have been acquired and archived. By 2006, side scan sonar data are expected to increase sevenfold.

NOAA's National Spatial Reference System

The health of the Nation's economy is directly dependent upon its ability to accurately reference its property and infrastructure. The NOAA-managed National Spatial Reference System (NSRS) provides a common geographic framework and is the fundamental infrastructure for all commerce, inland or marine. In conjunction with water level datum determination, NSRS is the basis for mapping, charting, navigation, boundary determination, property delineation, construction, resource evaluation surveys, and scientific applications. The accurate and consistent spatial reference provided by NSRS is critical to energy resource exploration and extraction as well helping to safeguard delivery, including import and export, of energy products. NSRS enables reliable land tenure and title systems. This system facilitates the efficient exchange and development of real estate, critical to the credit and mortgage industries.

NOAA validates, archives, and distributes data from the following components of the NSRS:

- A consistent, accurate, and up-to-date national shoreline;
- The National Continuously Operating Reference Stations (CORS), which are a set of Global Positioning System (GPS) stations meeting NOAA geodetic standards for installation, operation, and data distribution;
- A network of permanently marked points; and
- A set of accurate models describing dynamic geophysical processes affecting spatial measurements.

A major NOAA mission is to survey the United States' 95,000 miles of coastline and provide the Nation with an accurate, consistent, up-to-date national shoreline. The shoreline depicted on NOAA's nautical charts approximates the line where the average high tide, known as Mean High Water, intersects the coast. NOAA's shoreline mapping also provides the line where Mean Lower Low Water – or the average of the lowest tide levels – intersects the coast.

The method used today by NOAA to delineate the shoreline is stereo photogrammetry using tide-coordinated aerial photography controlled by kinematic GPS techniques. This process produces a seamless, digital database of the national shoreline and a database of aerial photography. NOAA is currently undergoing a transition from an analog-based shoreline compilation process to a digital-based process. When completed, this transition will not only enable NOAA to compile shoreline more quickly, but will also more efficiently populate the NOAA digital shoreline database and facilitate dissemination of requested shoreline data to the many users. These modernization efforts are anticipated to yield increased efficiencies, which will help NOAA move toward attaining an adequate mapping cycle.

Another aspect of NSRS is the national CORS system. CORS is comprised of some 300 ground-based stations that record GPS data on a continuous basis. Through NOAA's leadership, these GPS data are made freely available to the public via the Internet for applications that include 3-dimensional positioning, navigation, geophysics, and meteorology. The CORS system benefits from a multi-purpose cooperative endeavor involving more than 55 government, academic, commercial, and private organizations — each of which operates at least one CORS.

GPS Continuously Operating Reference Station (CORS) located near the Chatham Lighthouse, Massachusetts. This CORS station is one of 650 stations in the national CORS network managed by NOAA in cooperation with numerous partners. NOAA makes data from CORS publicly available to provide users with 3-dimensional positioning with an accuracy of a few centimeters.

A sampling of specific geodetic products provided via CD-ROM and online through the Internet includes:

- Geodetic "data sheets" for the 750,000 permanently marked geodetic control points;
- GPS data;
- Aerial photography used in shoreline mapping activities, and aeronautical data used to develop airport runway approach procedures and airport

obstruction charts;

- Online User Positioning Service allows users, including surveyors across the U.S., to input their own observations to NOAA over the Internet and to receive accurate coordinates (latitude, longitude, and height) based upon these observations and CORS data.

NOAA's Coastal & Ocean Observing Systems: Marine Observation Network

NOAA's Marine Observation Network (MON) is another "backbone" of NOAA's coastal and deep ocean observation systems. The MON supplies 24x7 real-time quality-controlled measurements and products that support NOAA's missions of protecting life and property, promoting safe navigation, and husbanding our Nation's protected species and natural resources. The MON serves as one of NOAA's fundamental observing systems, providing measurements that include *in-situ* wind speed, direction, and gusts; barometric pressure; air and sea surface temperature; relative humidity; wave height, period, steepness, power spectral density, and direction; surface currents; ocean currents and temperature profiles; and salinity. The network provides observations from a variety of data acquisition platforms that include moored buoys, drifting buoys and floats; over 800 vessels in the Voluntary Observing Ship program that transmit data periodically; and Coastal Marine Automated Network (C-MAN) stations.

NOAA maintains approximately 60 moored buoys and 47 C-MAN stations to acquire marine atmospheric and oceanographic data in support of NOAA's National Weather Service (NWS) warning and forecast program. The buoys and C-MAN stations are located around the United States in the deep ocean and coastal zones. The data acquired include wind speed and direction, peak wind gusts, air temperature, sea surface temperature, barometric pressure, and wave height. They are transmitted hourly via the Geostationary Operational Environmental Satellites (GOES) and are available to marine weather forecasters within 30 minutes. The data are available on the Internet and are accessed easily.

The current spatial distribution of MON stations has created significant observational gaps in the MON framework. Significant improvements in service could be achieved by improving the NOAA Observing System Architecture (NOSA). Upgrades to current technology in NOAA's data management information systems, coupled with refinements in the NOSA, could lead to more cost-effective observation systems and allow all NOAA observations to be more accessible to NOAA's customers when needed. Common interface standards could improve communications and data availability to sister agencies, such as the Environmental Protection Agency, Department of Interior's Minerals Management Service, U. S. Army Corps of Engineers, U.S. Coast Guard, and other parts of the Office of Homeland Security. All have a need for real-time, quality-controlled information.

In 2002, a ship carrying cranes for a new port facility came under the San Francisco Bay Bridge with just a few feet of clearance. Accurate water level information was critical in ensuring safe passage under the bridge.

NOAA's Coastal & Ocean Observing Systems: Water Level

For over a millennium, knowing the tidal water level has been essential for a mariner seeking to bring goods safely in and out of ports. In the last decade, ships have often moved mere inches from the bottom of narrow shipping channels. Knowing the water level very precisely relative to a known datum is the difference between a safe passage and running aground with the potential for disastrous and costly oil spills. Confirmation of exact water depths can also allow a ship to load hundreds of thousands of dollars worth of extra cargo, or to better time arrival or departure to avoid waiting for the next tide. Just one inch of additional draft, the amount a ship settles into the water, can yield increased revenues of up to $3 million. Having accurate tidal predictions or knowing actual (real-time), accurate water levels improves the efficiency of port operations while reducing the risks of groundings and collisions with overhead obstructions such as bridges.

NOAA's National Water Level Observation Network (NWLON), one of NOAA's coastal ocean observing systems, supplies long-term, sustained measurements of tides and water levels from 175 stations around the coast, including the Great Lakes, ocean island possessions, and territories. Some of the records contain data spanning more than 150 years, making them some of the longest geophysical records in the United States. In addition to supporting safe navigation by supplying critical water level information to mariners, NWLON serves as one of the fundamental observing system platforms for the NOAA tsunami warning system and provides the NWS with predicted and observed water level information needed for storm surge monitoring. Furthermore, it provides reference data for nautical chart products and the national shoreline; all marine boundary applications; and coastal construction of bridges, docks, and deep-water channels, dredging, surveying and mapping, and habitat restoration. Water level information and the associated tidal currents are used to help predict the behavior of hazardous spills. The data also are necessary in planning underwater demolition activities and other military engineering uses.

The NOAA tide station at Vaca Key, Florida Bay, supplies water level and storm surge data, wind speed, and air and water temperature to the community. This station is part of NOAA's National Water Level Observation Network (NWLON) comprised of 175 stations around the U.S. coast, including the Great Lakes and ocean island possessions and territories. Station data are transmitted ever 6 minutes to NOAA and made available over the Web to the public.

Some of the products and services resulting from NWLON include:

- Internet access, including telnet and File Transfer Protocol, to a standard suite of products that include data observations, predictions, inventories, historical data, tidal data, and benchmark information;
- Graphical representations of all observations and tidal predictions;
- Special hazards and event home pages providing observational data for the Federal Emergency Management Agency, NWS, and state and local agency emergency response teams;
- Special sea level variations and trends home page providing the latest sea level trends and monthly mean sea level anomalies; and,
- Historical records of the monthly and yearly highest and lowest observed water levels that provide

climatological information on the frequency and strength of coastal storms and hurricanes.

Ships are getting larger and drafts are getting deeper. Accurate navigational tools, such as PORTS®, are required.

NWLON also serves as the infrastructure for implementation of NOAA's Physical Oceanographic Real-Time System® (PORTS®), a decision-support tool that allows the marine community to immediately access critical data needed for safe navigation. In partnership with local port authorities, pilot associations, the U.S. Coast Guard, the U.S. Army Corps of Engineers, the U.S. Navy, academia, and others, PORTS® has been implemented in various bays and harbors in the United States to measure and disseminate water levels, currents, salinity, air and water temperature, winds, and atmospheric pressure in real-time. Nowcast/forecast models also are being incorporated into several of the PORTS® data suites to provide mariners with short-term water level and current forecast guidance for 24 to 36 hours into the future. Given this information, U.S. port authorities and maritime shippers can more effectively determine in advance when a vessel can safely enter or leave a port and how much cargo the vessel can carry before it is constrained by channel depths. PORTS® provides data dissemination to local users via voice, text, and the Internet. New technologies and ways for disseminating the data (such as cell phones) are being pursued.

The Continuous Operational Real-Time Monitoring System (CORMS) is a 24x7 system to quality control both PORTS® and NWLON data and, based upon set parameters, has the ability to discontinue data dissemination if quality or accuracy are in question. For example, if a salinity sensor became clogged with marine growth, the values could fall outside of expected parameters. Personnel monitoring CORMS would be notified by an alarm, would analyze the data, and decide to stop dissemination until the sensor was cleaned. This system is presently being upgraded to use knowledge-based expert software that will "learn" new data quality concerns and incorporate them into the monitoring. Continued enhancements are required as new sensor technology and new PORTS® sites are added. CORMS also monitors the operational nowcast/forecast model activity.

An improved quality-control system for the meteorological sensor data acquired at various NWLON sites is needed, along with the availability of user-driven products. Also, funding efforts are underway to both fully configure the NWLON for real-time data acquisition and dissemination, and to completely digitize the historical data series and make them available over the Internet along with their supporting metadata. As the number of PORTS® sites increases, accessing data via the telephone may prove to be inadequate; capturing the data via satellite is being investigated.

NOAA's Surface Transportation Partners and Support to Decision Makers

NOAA provides real-time observations and analyses of temperature, wind, pressure, precipitation, and visibility to support the Nation's diverse land-based economy. Its core expertise and long history of documenting environmental conditions in the United States position it as an authority in siting, reporting, and data management practices for the Nation's environmental data.

NOAA provides support to its numerous federal, state, and private partners, including: Departments of Defense, Transportation (Federal Highway Administration (FHWA), Interior (U.S. Geological Survey and

Bureau of Land Management), Energy, Agriculture, and Homeland Security (Transportation Security Administration and Federal Emergency Management Agency), Environmental Protection Agency, Nuclear Regulatory Commission, and state and local agencies.

NOAA's contribution to the surface observing system impacts the following parts of the U.S. economy: 3.9 million miles of roads, 120,000 miles of railroad tracks, 200,000 miles of gas and oil pipelines, 5,400 airports, and 6,600 miles of urban transit rail.[3,4,5] About 41,000 people die on U.S. roads every year in 3 million crashes. Seven thousand (17 percent) of these deaths and 800,000 crashes (27 percent) are weather-related with an economic impact from injuries, deaths, and crashes estimated to be $42 billion annually.[13]

While not all weather-related accidents can be avoided, a significant number of deaths and injuries, and their associated costs, can be avoided through improved observations, communications, and forecasts. One study showed that 83 percent of accidents and 62 percent of road maintenance labor can be avoided with an accurate forecast that could trigger anti-icing pre-treatment.[14] NOAA's nationwide surface and weather radar observing network, coupled with state Department of Transportation Road Weather Information Systems (RWIS), provides the foundation for this capability.

NOAA is an integral component in supporting the following partners' surface transportation decision support systems -- *FORETELL* and the *Advanced Transportation Weather Information System (ATWIS)*:

FORETELL is a multi-state initiative covering the Upper Mississippi Valley region and funded in part by the FHWA. The goal of the FORETELL program is an RWIS integrated with a wider set of Intelligent Transportation System services to enhance safety and facilitate travel. FORETELL provides detailed weather forecasts, generated four times per day for the next 24 hours, with hourly updates, available to users via the public Internet. Spatial resolution is on a 10-km grid, and the forecasts are mapped to interstates and highways to predict pavement conditions. It also collects atmospheric and road condition observations from roadside sensors and mobile platforms, processing them into "plain English" descriptions for users.

ATWIS provides in-vehicle information on road conditions as well as weather forecasts. ATWIS began as a means of providing route-specific road condition reports and nowcasts (forecasts from the current time through the next six hours) by cellular telephone to rural travelers in the northern Great Plains. The weather forecasts, which are updated hourly, provide information from a traveler's present location (specified by saying the interstate highway mile marker and direction of travel) to approximately 60 miles down the traveler's route. Road weather observations, including road surface conditions, are acquired through coordination with the state departments of transportation.[15] ATWIS currently is available in three states (North and South Dakota and Minnesota), covering 96,000 miles of highway. Surveys conducted by an independent evaluator found that 94.3 percent of travelers who knew of the service believed it would benefit their safety in the future.

NOAA's Weather Observing Systems

NOAA sponsors and operates a variety of observing systems on land, in the oceans, from aircraft, and from satellites in space. In addition, there are more observing systems operated by other federal, state, and local agencies, the private sector, and foreign countries.

NOAA operates a suite of satellites and *in-situ* climate observing systems, which support the monitoring of the Earth's climate and weather systems. The NOAA National Data Centers (NNDCs) (comprised of the National Climatic Data Center (NCDC) in Asheville, North Carolina; National Geophysical Data Center (NGDC), Boulder, Colorado; and National Oceanographic Data Center (NODC), Silver Spring, Maryland) are responsible for the long-term stewardship of the significant amount of environmental data and information collected from the *in-situ* (land and ocean), airborne, and space-based NOAA and non-NOAA sources. These NNDCs are also part of a global network of designated World Data Centers, which manage and share the data from international partners who operate observing systems.

The data from the satellites and climate observing systems are ingested, inventoried, documented, quality controlled, analyzed, archived, and made accessible. Access to global observations provide researchers, businesses, and decision-makers the global perspective required to be economically competitive, conduct research, and formulate policies and decisions. A broad and diverse worldwide clientele have unprecedented access to a wide variety of observations that provide the basis for informed decisions by policy makers, climate researchers, the public, and small and large businesses in every economic sector (e.g., energy, agriculture, water resources, transportation, engineering, health, recreation, etc.). The array of these observational data sets ranges from tree rings and ice cores, to hand-written daily weather observations, to billions of bits of remotely measured data from weather radars and satellites. Managing and extracting useful information from these ever increasing and complex data sets are on-going challenges for the NNDCs.

Automated Surface Observing System (ASOS)

The Automated Surface Observing System (ASOS) is the Nation's primary surface weather observing network. ASOS provides reliable, 24-hour per day, continuous surface weather observations at approximately 1,000 airports nationwide. NOAA's NWS owns and operates 330 of the stations and operates the remaining stations under reimbursable agreement with the Federal Aviation Administration (FAA). ASOS observation parameters include wind, temperature/dew point, pressure, cloud height/coverage, rain/snow/freezing rain discrimination, visibility, rain accumulation, fog, haze, and thunderstorm potential.

Once ASOS data are collected from their source, they are initially quality controlled at the sensor using internal gross error checking and system alarms. This is followed by more rigorous quality control by both software and humans. The data are stored at the local NOAA NWS Weather Forecast Offices (WFOs) for a period ranging from one to five days to support NOAA's protection of life and property mission, and then the data are transferred to the NOAA NCDC for long-term storage.

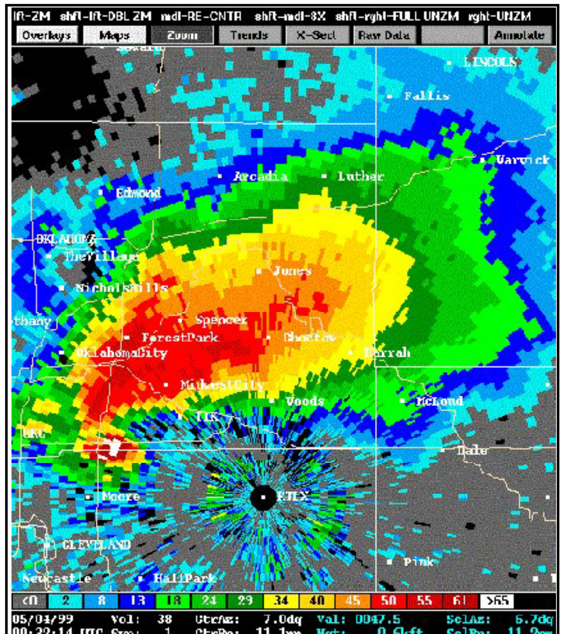
Cooperative Observer (COOP) Network

Today, the Cooperative Observer (COOP) network forms the only comprehensive, nationwide, unbiased source of weather and climate observations in the United States. The network is the Nation's largest and oldest climate/weather network. The observations provide the bulk of historical climate data for the United States. The network was established in 1890. Observers submit monthly summaries of their 24-hour manual observations to the NOAA NCDC for quality control, archiving, and publication. Currently, the network consists of 11,700 volunteer-operated surface observing sites which record precipitation on a daily basis, with approximately 5,500 of these sites also recording daily high and low temperatures.

The modernization of the COOP network entails the addition of automated weather sensors and real-time communications and processing capability. This initiative will provide the Nation with an adequate network of accurate surface data obtained with state-of-the-art measurement, monitoring, and communication equipment, universally available via the Internet. The modernized network will ensure the continuity of the Nation's climate record, meet the exploding demand for higher density, real-time surface data by weather-sensitive industries (e.g., energy producers and the weather risk industry), along with private and public weather services, and will provide a new comprehensive data source for improving local forecasts and longer term climate forecasts.

Next Generation Weather Radar (NEXRAD)

NOAA's NWS operates and maintains a network of 121 Doppler weather radars used for severe weather detection and local forecasting (i.e., rainfall amounts). The NWS radars are a substantial component of the total 158 NWS, FAA, and Department of Defense (DoD) NEXRAD radars. The NEXRAD network is the primary means for detecting, forecasting, and warning for severe local weather events such as thunderstorms, tornados, and flash floods. Doppler radars also provide area precipitation measurements, important in forecasting potential flooding. The NEXRAD network since its deployment has contributed to a dramatic increase in average tornado warning lead times. In the pre-NEXRAD era, lead times were five minutes or less. Now, the average lead time for such warnings has doubled to 11 minutes. Improved lead times for just one event may have dramatic effects. For example, warning lead times issued well in advance of the May 3, 1999, Oklahoma City barrage of tornadoes were estimated to have saved 684 lives. In particular, the NOAA NWS WFO in Norman, Oklahoma, issued the first tornado warning for the tornado that struck Oklahoma City approximately one hour before it hit.



This is a National Weather Service Twin Lakes Oklahoma WSR-88D radar reflectivity image from 7:28 pm, May 3, 1999 displays a hook echo from a violent (F4) tornado that swept through the Oklahoma City suburbs. There are 158 operational WSR-88D radars covering the United States. The imagery and data from all radar sites are archived and accessible through NOAA's National Climatic Data Center.

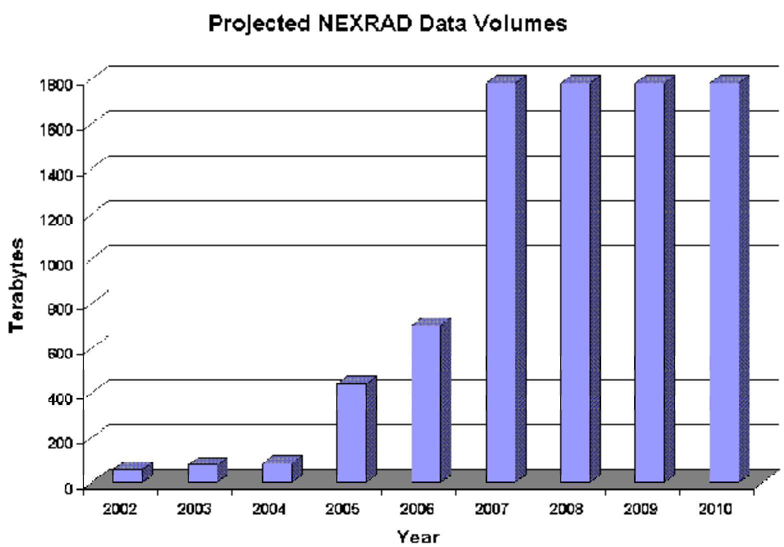
Current NEXRAD product improvement program activities underway include the Open Radar Data Acquisition (ORDA) effort to replace the current signal processing equipment with improved commercial-off-the-shelf units and the Dual Polarization program, which includes replacement of the radar signal generator with improved signal technology. The Fiscal Year 2004 President's budget accelerates the deployment of the ORDA, and provides for some Dual Polarization improvements. The acceleration of ORDA may enable the NWS to improve tornado warning lead times from 11 minutes to 15 minutes by 2007 and save $2.4 million from the total cost of the NEXRAD Product Improvement Program.

The ORDA systems will double the range for detection of small tornadoes from 120km to 240km, increase coverage area for small tornado detection by 80 percent, and decrease volume scan time from 5 minutes to 2.5 minutes. Dual Polarization information will enable NWS forecasters to provide better rainfall estimates and precipitation identification, as well as provide information on aircraft icing potential.

The data will allow forecasters to discriminate between rain, snow, and ice pellets, thus providing much improved snow accumulation estimates. The ability to filter out what weather forecasters call "clutter" (technical name "anomalous propagation"), which can significantly degrade precipitation amount and wind estimates, will be improved. Clutter is caused by fixed obstacles, such as trees, buildings, and hills near the radar, as well as transient objects such as birds and insects. Dual Polarization data will allow the NEXRAD to remove these "clutter" errors and significantly improve the accuracy of the wind and precipitation observations.

"An alert theater manager in Van Wert, Ohio, was listening to early warnings on his weather radio on Sunday, Nov. 10, and cleared an auditorium of matinee movegoers in time to avoid disaster. A tornado hurled these cars onto the seats. Paul Van Dyke is a volunteer ham radio spotter . He took the photo while accompanying NOAA staff on a storm survey."

These improved capabilities of NEXRAD also pose data management challenges. The additional information resulting from the deployment of the ORDA and Dual Polarization capabilities will increase the amount of (uncompressed) data by a factor of almost 30 by 2010. This increase will significantly impact NOAA's communication and data storage infrastructure. NOAA also will be challenged to maintain continuity of precipitation, wind velocity, and derived product algorithms as the NEXRAD system is upgraded.



NOAA's Aviation Data and Partners

NOAA provides real-time observations and analyses of temperature, wind, pressure, clouds, turbulence, volcanic ash, and icing to support the Nation's general aviation, package, and commercial carriers. NOAA's atmospheric and radar observing systems form the backbone of an expanding public/government partnership for observing the Nation's airports and air corridors that make up the National Aerospace System.

It is estimated that air traffic delays result in an annual $6 billion loss to the economy, of which 70 percent of the delays are attributed to weather.[16] NOAA works with its partners in the FAA, research associates, and private industry to minimize impact of weather on aviation interests.

NOAA observing systems are an integral component of the larger U.S. transportation economy as well as the following partners' (FAA, airport authorities, and air carriers) aviation decision support systems:

- Corridor Integrated Weather System
- Integrated Terminal Weather System

NOAA data used by these systems includes NEXRAD, radiosonde, wind profilers, and the ASOS.

NOAA's Upper Air Observing System: The Radiosonde and Profiler Network

The NWS Radiosonde network provides upper-air weather observations consisting of temperature, pressure, humidity, and wind speed/direction. Measurements are taken twice a day at 102 locations nationwide.

Radiosondes are the primary source of *in-situ* data required by NWS numerical weather prediction models that form the basis of all NWS forecasts for day two and beyond. While satellite data comprise the majority of all data used in Numerical Weather Prediction models, actual meteorological measurements taken of the atmosphere from radiosondes are critical to "initialize" the models and validate satellite measurements.

NOAA operates the NOAA Profiler Network (NPN) which contains 35 stations providing a vertical wind profile from the surface to approximately 53,000 feet, every hour. The NPN stations are primarily distributed throughout the central United States.

NPN data are used to monitor the atmosphere to determine the potential for severe thunderstorms, trajectory of heavy snowfall areas, possibility of low stratus and surface visibilities, as well as for real-time flight level winds for aviation route and fuel planning.

C. Hazards

NOAA's Geostationary and Polar Satellite Systems: Hazard Sentinels

Today, satellites provide continuous global surveillance to allow determination of the location, size, and intensity of developing storms. They detect wildland fires and provide airline and utility companies information about impending solar activity.

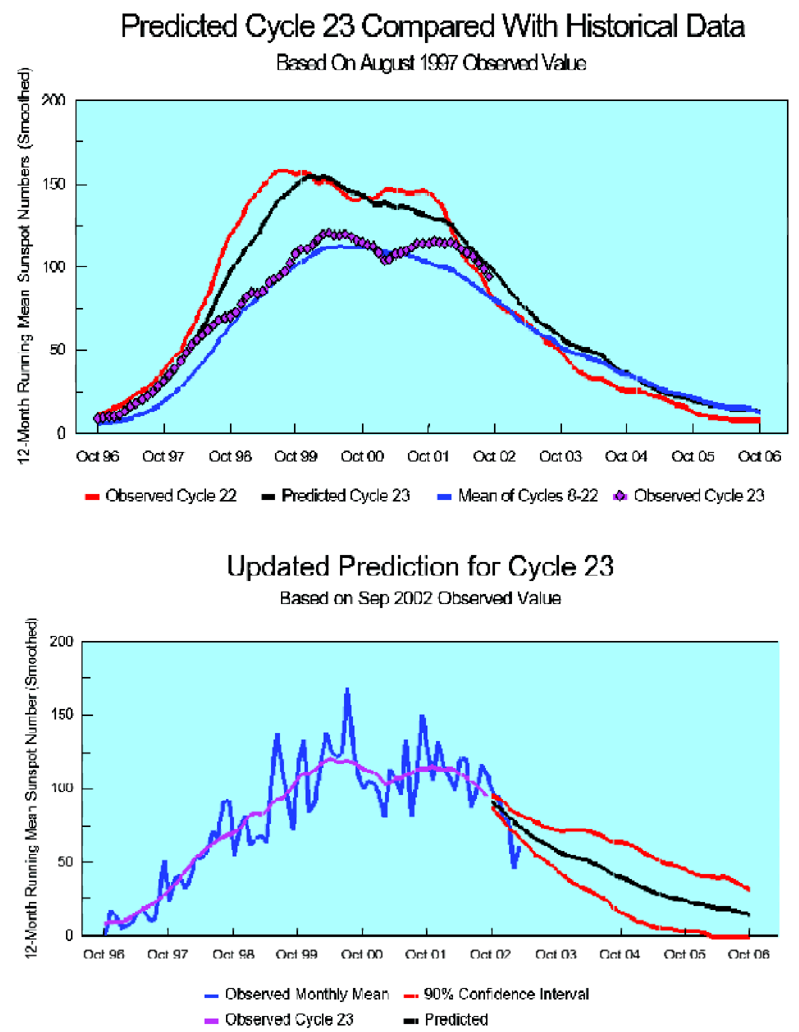
NOAA operates the Nation's civil geostationary and polar-orbiting environmental satellites, and manages the largest collection of atmospheric, geophysical, and oceanographic data in the world. These activities are critical to monitoring of the environment, and analysis of hazards potential.

GOES satellites provide national and regional short-range warnings and nowcasting capability. Positioned over the Equator at approximately 22,300 miles above Earth, two operational satellites provide continuous monitoring of the Earth's atmosphere and surface over the Western Hemisphere. Imagery from these satellites is used to monitor potentially severe weather conditions. Infrared channels can help to detect forest fires, sea surface temperature, fog formation, and volcanic plumes.

Polar-orbiting operational environmental satellites (POES) provide global long-term forecasting and environmental monitoring. These satellites are north-south orbiting at 500 miles above the Earth, two operational satellites viewing the entire planet approximately every 6 hours. Data from POES support a broad range of applications, including climate research, ocean dynamics studies, drought and forest fire detection, and vegetation analyses.

Data from the U.S. Air Force's Defense Meteorological Satellite Program (DMSP) are archived by NOAA and are used to monitor cloud density, city lights, fires, and energetic particles from the Sun (which cause aurora and other upper atmospheric phenomena).

Currently, on a daily basis, NOAA ingests and manages approximately 51.5 GB of GOES data, 6.3 GB of POES data, and 5.5 GB of DMSP data, most of which are used for hazard, weather, and climate monitoring applications.



Sunspot data are used to predict the intensity of solar activity within cycles. Historical and current data are combined to create these analyses. The graphs show that October 2002 is nearing the end of a cycle; solar activity is slowly declining. NOAA Satellites monitor and collect data on solar activity.

NOAA's In-situ Observations for Hazard Monitoring

In-situ observations are those collected from individual locations on the ground, in the ocean, or in the air. A rain gauge at a commercial airport, a ship report of wave height, measurements from a geomagnetic observatory, or a ship's survey path measuring ocean bathymetry are examples of *in-situ* environmental monitoring.

Such on-site observations are necessary for the calibration of satellite sensors, filtering of space-borne data contaminants, and to aid in satellite drift adjustments. Satellite instruments observe Earth's surface and atmosphere through the entire depth of the atmosphere. Any atmospheric contamination (such as clouds or airborne particles) limits the instruments' ability to detect the atmospheric conditions near Earth's surface.

In-situ data platforms are often used in tandem with satellites, providing geographic referencing. The GOES Data Collection System can receive transmissions such as those from buoys, sensors onboard aircraft, and river gauges, and relay the information back to the owner of the platform. This allows for near-real-time use of data.

There has been a tremendous growth in using NOAA satellite and *in-situ* data with geographic information systems, global positioning systems, and computer modeling. Each application adds significant value in monitoring and assessing potential natural and man-made disasters. This is essential to rapidly deploying resources in both pre- and post-disaster situations.

NOAA Hazard Data Observations: Hurricanes & Severe Weather

Each year, on average, 10 tropical storms (of which six become hurricanes) develop over the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico. An average of five hurricanes strike the U.S. coastline every three years, of which two will be major hurricanes (with wind speeds exceeding 111 miles per hour). More dangerous than the high winds is the accompanying storm surge, which can devastate coastal communities as it sweeps ashore. This is what destroyed Galveston, Texas, in 1900, causing 6,000 deaths. In recent years, fatalities associated with storm surges have been greatly reduced as a result of better warnings and enhanced preparedness within coastal communities. On an average annual basis, $2.5 billion in damage costs are *not* incurred as a result of more accurate hurricane watches and warnings. The economic impact of lives saved accounts for $1.45 billion of the $2.5 billion, and $1 billion is due to spared property.[17]

Each year NOAA's National Weather Service (NWS) issues more than 734,000 fire weather, public, aviation, and marine forecasts; 850,000 river and flood forecasts; and nearly 30,000 potentially life-saving severe weather warnings from 122 forecast offices.

Complex numerical weather forecast models that form the basis for the forecasts and warnings require a supercomputer that handles over 3 trillion calculations per second. It would take a hand-held calculator 5,000 years, working 24 hours a day, 7 days a week, to perform the calculations that the supercomputer accomplishes in one second.

Instruments on GOES and NOAA and U.S. Air Force aircraft that fly into hurricanes determine hurricane location, size and intensity. As hurricanes approach land, forecasters along the U.S. coasts monitor storm movement through the use of the NEXRAD radar network. NOAA's National Hurricane Center provides detailed media information and forecasts to predict where and when the hurricane will hit land, aiding in determining if, when, and where to evacuate. The data are archived and accessible at the NNDCs.

NOAA began to issue five-day hurricane forecasts when the 2003 hurricane season began on June 1st. Data from the 2001 and 2002 testing periods indicate that the five-day track forecast will be as accurate as the three-day forecast was 15 years ago. Earlier awareness will increase public safety, allowing for longer preparation time.

NOAA issues about 26,900 warnings, advisories, and statements annually from 122 NWS WFOs for the Nation's 3,066 counties, parishes, and boroughs. Thirteen NWS River Forecast Centers issue hundreds of river stage and flood statements for 792 river basins.

Severe storms can cause death and extreme destruction and can have a major impact on the economy. A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. Extremely cold temperatures, snow accumulation, and sometimes coastal flooding, can cause long-term hazardous conditions.

More than 10 percent of the estimated 100,000 thunderstorms per year are classified as severe. The term is applied to storms with wind gusts greater than 58 miles per hour or hail 3/4 inch diameter or larger.

Although violent tornadoes comprise only two percent of all tornadoes, they are responsible for 70 percent of tornado-related fatalities. There are no areas immune to tornadoes. More than 1,000 tornadoes are reported annually nationwide, and as tornado detection systems improve, more are being reported each year.

Extreme heat accompanied by high humidity and sometimes accompanied by stagnant atmospheric conditions creates dangerous stresses in humans. NOAA provides a "Heat Index" and excessive heat guidelines tailored for major metropolitan centers based upon city-specific meteorological conditions. NOAA monitors drought conditions throughout the year, issuing short term and long-term forecasts.

A prototype of the North American Drought Monitor, based upon the United States Drought Monitor, has been developed by representatives from meteorological, hydrological, climatological, and agricultural agencies from Canada, Mexico, and the United States. The United States agencies participating in this effort include NOAA, the Joint Agricultural Weather Facility (Department of Agriculture), and the National Drought Mitigation Center. Once the peer review is completed and approved by Canadian, Mexican, and United States Government officials, the North American Drought Monitor will be introduced to the public sometime during 2003.

NOAA Hazard Data Observations: Space Weather

Space weather has a significant effect upon energy providers, communication, transportation, and space exploration interests. The Sun periodically generates geomagnetic solar storms that have caused massive power outages. The economic value of an operational geomagnetic storm forecasting system in the North American electricity industry is estimated at about $450 million over three years.[18]

Instruments aboard NOAA's polar-orbiting satellites are used to provide a space weather storm warning system. The space environment monitor aboard NOAA's most recent geostationary satellite mission (GOES-12) is designed to provide real-time measurement of space weather, flares, solar radiation storms, radio blackouts, and geomagnetic storms. Researchers and data modelers work together to improve information analyses using the data collected from these satellites.

NOAA Hazard Data Observations: Seismological Hazards

Tsunamis are ocean waves produced by earthquakes or underwater landslides. As the waves approach the coast, their speed decreases and their amplitude increases. The waves can be very destructive and cause many deaths or injuries. Earthquake-induced movements of the ocean floor most often generate tsunamis. Landslides and volcanic eruptions can also generate a tsunami. If a major earthquake is felt, a tsunami could reach the beach in a few minutes, even before a warning is issued.

The United States is the third in the world, after Japan and Indonesia, for the number of active volcanoes. Most of the Nation’s volcanoes are in Alaska. However, the United States may experience effects from volcanoes that erupt in other geographic regions. Volcanic ash consists of fine, glassy rock fragments that can affect people and equipment hundreds of miles away from an eruption. It poses an ever-increasing threat to aviation safety as transportation expands throughout the Pacific Rim. Airborne ash can diminish visibility, damage flight control systems, and cause jet engines to fail. NOAA meteorologists track volcanic eruptions throughout the world and monitor all available satellite images for ash plumes. In collaboration with the FAA, the International Civil Aviation Organization, and other ash advisory centers worldwide, NOAA develops volcanic ash advisory statements. Pilots are warned to avoid routes with a high probability of danger. NOAA currently archives two gigabytes of tsunami-related seismology and volcano data.

NOAA’s Hazard Data Management Responsibilities

During the occurrence of an extreme event or disaster, NOAA collects and manages real-time data and communicates hazard information and warnings. This information assists first responders in their task of emergency management. In the recovery period after an event, NOAA documents what happened with the goal of understanding physical processes and improving modeling, forecasting, and warning.

NOAA provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas. NOAA is the sole United States official voice for issuing warnings during life-threatening weather situations, and also provides watches and warnings for non-weather hazards.

NOAA’s flood forecasting function relies almost entirely upon automated data as opposed to manual observations. Other federal agencies, including the U.S. Geological Survey, contribute to these flood forecasting services. Real-time data are transmitted from field sites using a variety of techniques that include line-of-sight radio, microwave, and satellite.

The data are screened for quality before being placed into computer models. Each geographic region has models configured to its own parameters. Flood forecasting involves a skilled balance of experience, analyses of current conditions, and analyses of model results. This leads to site-specific warnings, watches, and advisories.

NOAA issues daily forecasts, alerts, warnings, and watches about disturbances in the solar-terrestrial environment. At times of high solar activity, NOAA’s space environment Internet pages record more than one million queries per day.

As part of an international cooperative effort to save lives and protect property, NOAA operates two tsunami warning centers. The Alaska Tsunami Warning Center in Palmer, Alaska, serves as the regional Center for Alaska, British Columbia, Washington, Oregon, and California. The Pacific Tsunami Warning Center in Ewa Beach, Hawaii, serves as the regional Center for Hawaii, and is an international warning center for tsunamis that pose a Pacific-wide threat.

Tsunami watch, warning, and information bulletins are disseminated on a geographical basis. In addition to regular media coverage, NOAA Weather Radio also provides direct warning information to the public. The U.S. Coast Guard broadcasts this information via medium- and high-frequency marine radios.

NOAA's Data and Services for Hazardous Incidents: Fires and Drought

Each year more than 100,000 wildland fires occur in the United States. Lightning starts about 10 percent of these fires, while humans start the remaining 90 percent. NOAA and non-NOAA satellite data are used to identify hot spots and track smoke plumes. Computer models determine air quality forecasts, important for the medical community's response to fire-related symptoms. NOAA also integrates hot spots and smoke plumes with the goal of integrating other fire information such as forecasts of smoke plumes, wind, and air quality into a GIS fire hazard mapping system. This system gives wildland fire managers the ability to make informed decisions about deploying assets and enhancing firefighter safety. For example, wildland fire managers can use the system to display and zoom in on areas of interest, and to look at selected hazard parameters of interest, such as fires and smoke. A map underlying these parameters provides selected information (state and county boundaries, rivers, lakes, and interstate highways) that can help fire managers determine where the fire is, how close heavy equipment can be brought, an evacuation route for firefighters in danger, and if local water sources are available to help put out the fire. Wildfires can strip steep hillsides of all vegetation, increasing the likelihood of flash flooding and mud slides until vegetation returns. They can also lead to destructive debris-flow activity. In July 1994, a severe wildfire swept Storm King Mountain in Colorado, denuding the slopes of vegetation. Heavy rains two months later resulted in numerous debris flows, one of which blocked Interstate 70 and threatened to dam the Colorado River.

NOAA's Data and Services for Hazardous Incidents: Floods

Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. As much as 90 percent of the damage related to all natural disasters (excluding droughts) is caused by floods and associated debris flows. Most communities in the U.S. can experience some kind of flooding. Melting snow can combine with rain in the winter and early spring; severe thunderstorms can bring heavy rain in the spring and summer; or tropical cyclones can bring intense rainfall to the coastal and inland states in the summer and fall.

Flash floods typically occur within six hours of a rain event, after a dam or levee failure, or following a sudden release of water held by an ice or debris jam. Urbanization increases runoff two to six times over what would occur on natural terrain. Streets can become swift-moving rivers, while basements and viaducts can become death traps.

Landslides and debris flow are typically associated with periods of heavy rainfall or rapid snow melt, and tend to worsen the effects of flooding that often accompanies these events. They may also be associated with volcanic events. Pyroclastic flows, hot ash, fallen trees, ground water, and rainwater create destructive mudflows and flooding.

The Advanced Hydrologic Prediction Service is based upon computer models of rainfall, water runoff, and river channel flow data, plus the historical record of these parameters for given forecast points and small watersheds. These models extend the current one to three-day river stage forecast lead times to weeks or even months in advance. These types of data are essential for risk-based decision making in the local response community. National implementation of the Advanced Hydrologic Prediction Service will save lives and an estimated $240 million per year in flood losses, and will contribute an additional $520 million per year in economic benefits to water resources users.[19]

NOAA's Data and Services for Hazardous Incidents: Environmental Spills and Long-Term Contamination

NOAA is the focal point for spill preparedness and response, hazardous waste site investigation, and environmental damage assessment activities. During a spill, NOS utilizes NOAA's resources, including charting capabilities, accurate weather information, and hydrologic data, to provide the best recommendations for responding to the spill in the most environmentally friendly manner. This information is used within modeling programs and given directly to the person in charge of the response. NOAA also provides rapid assessment of injuries to marine life and other NOAA trustee resources at oil spills. For many Superfund sites, NOAA provides damage assessment and guidance to the Environmental Protection Agency to create environmentally sensitive remedies to long-term pollution and works with local agencies to achieve environmental restoration when sudden or long-term hazardous material pollution occurs.

NOAA's software, databases, and other tools help emergency organizations respond to hazardous materials accidents and resolve contamination problems. NOAA computer models analyze oil spill trajectory and air dispersion of chemicals. An incident news web site provides timely information to the public about oil and chemical response operations during large incidents. Environmental Sensitivity Index Atlases provide standardized information on coastal habitat and human uses along the coast. These are used by spill responders and contingency planners to identify sensitive habitats, priority protection areas, and human uses of the coast, and to determine best protection strategies in case of and during a spill response. For long-term contamination, watershed database and mapping projects, developed within NOS, are used to pull together many different environmental contamination data sets for easy cross-reference and viewing within geographic information systems for decontamination planning, restoration, and damage assessment liability.

NOAA's Data Supporting Hazards: Dual Use

Satellite and *in-situ* instruments originally designed for real and near-real-time use; such as, weather forecasting, warnings, and monitoring have been used for many other environmental purposes. For example, instruments on polar satellites monitor the entire Earth several times per day and have provided a consistent set of data for more than two decades. Therefore, their information can be applied to both real-time and long-term aspects of disaster monitoring such as climate change.

In particular, the Advanced Very High Resolution Radiometer (AVHRR) instrument, which resides on POES, works in concert with other satellite and *in-situ* data, and is used to detect and monitor fires. It is the only high-density Earth observing instrument boasting a global history of more than two decades. This same fire information is also a key component of climate change monitoring and the carbon cycle affecting global warming. The Integrated Global Observing Strategy Carbon Cycle Theme has a team of scientists who study AVHRR data from around the world. They are working together to create a consolidated analysis in order to help determine if gases from fires contribute to global warming.

NOAA Historical Data Used in Hazard Support

Preparedness means that one anticipates the hazardous effects and takes appropriate countermeasures in advance, such as issuing warnings, stockpiling supplies, or establishing evacuation routes. Mitigation involves long-term actions taken to prevent or reduce a hazardous effect from occurring, such as building structures that can withstand the force of winds or earthquakes.

Traditionally, local governments have emergency response teams or committees which draft hazard response plans after considering data, statistics, or environmental indicators. NOAA data and analyses are used in these planning efforts.

NOAA historical data collections are broad in scope and critical to assessment. Long-term data can be used to establish the past record of natural hazard event occurrences, and contribute to awareness of future risk.

NOAA maintains environmental records from a myriad of sources. Weather observations have been manually recorded at hundreds of U.S. locations since the 1700s, providing over a 200-year record of the Nation's environment. Hydrographic and fish surveys provide a history from the mid-1800s. Data collected by remote sensing systems, such as radar and satellites, have been providing records for the past 40 years.

Proxy data gathered from the natural record come from sources such as ice core samples, ocean sediments, fossil pollen, coral skeletons, and tree rings. Proxy data extend the understanding of the climate far beyond the instrumental record and enable reconstruction of past climate conditions.

NOAA Data for Hazards Management: Current and Future Challenges

Today, NOAA provides long-term stewardship for environmental data, including improved data access and accuracy. NOAA also provides value-added data services to those who deploy resources before, during, and after disasters occur. NOAA's research has led to more timely warnings for extreme weather events and scenarios such as dispersion of hazardous materials, all the more critical since the attacks of September 11, 2001. NOAA is also able to generate long-term predictions of climate shifts. Improved warnings, forecasts, and predictions have been proven to save money, property and lives.

NOAA provides vital input to current and future disaster management planning and response. In the aftermath of the attacks of September 11, 2001, and continued terrorist threats, interagency and public-private partnerships have increased. These partnerships continue to strengthen national security. These also enhance the efficiency of response and recovery already in place for natural and man-made disasters. At the heart of improving disaster response is information coordination among the key players.

Information technology continues to transform the data distribution process, allowing quicker access to data essential for natural hazards research and mitigation. In the future, NOAA products and systems will continue to enhance data utilization at several levels – from the data manager who organizes data to the end user who views the data. Creative uses of new technology, combined with NOAA satellite data and historical records, will continue to lead to breakthroughs in hazards detection, assessment, and management.

Computer speed and functions will continue to increase with a corresponding decrease in cost. This will enhance the capabilities of forecasters to extract critical historical information and predict natural hazards probabilities. Advances in satellites, radar, and super-speed computers are the foundation of tomorrow's warnings and forecasts. However, tried and true methods such as radiosondes (balloon-launched weather monitoring units), moored buoys, and other *in-situ* instruments will continue to be used.

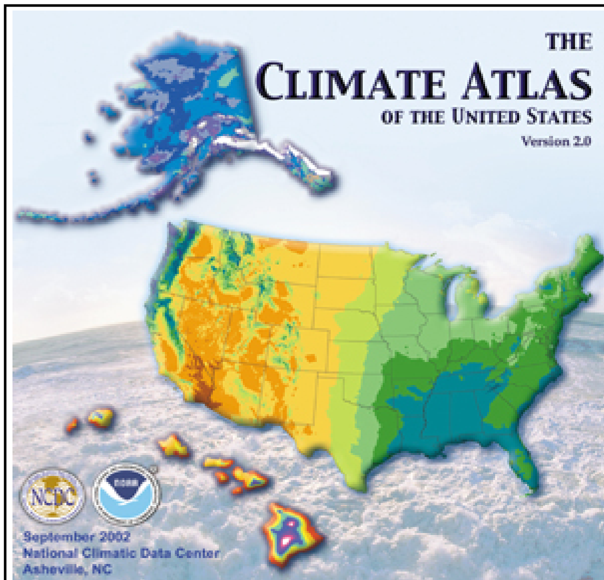
Challenges for the future include the integration of satellite and non-satellite information and model forecast output into geospatial, temporal information systems. Traditional GIS's tend to focus on layers of information in the two-dimensional geography of the Earth's surface. Many hazards require information layers that are updated frequently (e.g., minutes or hours) for satellite precipitation estimates or river gauge river stages in support of flash flood forecasting. They also have a vertical component, i.e., upward through the atmosphere for satellite monitoring and dispersion model output for volcanic ash clouds in support of aviation safety.

The challenges of managing data for disasters are similar to those of other data uses. However, they are exacerbated by often near-real-time requirements and dependency upon high-resolution, high-volume data. For example, adding fire detections as determined from the Moderate Resolution Imaging Spectrometer (MODIS) instrument on the National Aeronautics and Space Administration (NASA) Aqua and Terra satellites has improved the quality of the fire hazard mapping system. MODIS data is being used increasingly for hazard and other NOAA products. The data volume from MODIS ingested and managed by NOAA is approximately 175 GB, three times that from NOAA's own GOES and POES satellites.

D. Climate Monitoring

Why should NOAA Monitor?

Evaluating the past, monitoring and evaluating the present, and making future projections of climate trends, variations, and change are critical scientific pursuits. Humankind must understand the factors and processes influencing climate change, establish strategies to minimize human induced influences, and prepare society to respond to the potential impacts on the quality of life on Earth. Humankind's efforts to model and understand how the environment is changing will continue for many decades. However, the first step toward providing high confidence information to decision-makers is to ensure the observations used to monitor, evaluate, and predict climate trends and changes are of the highest climate quality possible.



NOAA's National Climatic Center published a CD-ROM of version 2.0 of the Climate Atlas of the United States in September, 2002. This replaces the popular paper atlas last published in 1968, and supersedes version 1.0 of the atlas published in 2000. The atlas contains over 2,000 color maps of climatic elements such as temperature, snow, wind, etc. that portray the climate of the United States. The period of record of the data for most of the maps is 1961-1990.

The President's Climate Change Research Initiative (CCRI) and the emerging Climate Change Science Program (CCSP) underscore the need for improved climate quality observations, improved monitoring and evaluation of climate trends, variations, and change as well as development of improved forecast models, and relevant and informative decision support products and services. Improved climate monitoring will lead to a better understanding of the causes and potential impacts of climate trends and change on the environment and human society, thus providing the opportunity to plan and respond accordingly. Climate quality observations and monitoring, in conjunction with increased confidence in reliable research, will enhance environmental literacy and education.

The U.S. Global Change Research Program Report[20] addresses a range of climate change issues. The report presents a credible scientific case for climate monitoring, evaluation, and assessing climate change. The potential impacts upon the environment and human activities provide the basis for establishing activities that monitor, evaluate, and predict climate trends, variability, and change.

The climate record to be used by researchers is based upon both current and past observation records. Knowledge of the local climate has always been a valued commodity. Those who could make sense of such information and forecast events have long been in demand by society. Monitoring, evaluating, and understanding changes to our environment in a modern, densely populated, and globally interrelated economic and cultural systems are now more important than in the past.

The record of life on Earth is clear. Climate change, both gradual and rapid (in terms of geological time), is a recurring, dynamic, and constant theme inevitably leading to the demise of species, the rise of new species, and adaptation by other species. Climate observations by humans trace back thousands of years. Farmers and mariners kept records of the annual cycle – the march of the different seasons through the year. Farmers used this knowledge to plan their plantings and harvests. Mariners adjusted shipping routes according to the seasonal winds and storms. In early American society, several of the founding fathers were avid keepers of climate records. Most prominent was Benjamin Franklin whose detailed logs of daily temperature, precipitation, and other weather notes are among the first climate records of the United States. In the late 1800s, the U.S. implemented a more organized national weather observation program, principally to support agricultural purposes. Those most involved with weather sensitive activities noted unusual alterations in the typical weather patterns, but could not explain these. Longer term trends often exceed the average life span of one or two generations. Humankind did not then have the perspective or information to understand the causes for unusual variations, trends, and long-term changes. However, humans and other species had to adapt to these changes or perish.

Today, more than 200 years of "modern" records provide the core of the most recent climate history of the Nation. Educational and technological advances of the 20th century have, for the first time, provided the means to frequently and simultaneously measure, record, and report many different climate parameters over large areas. Very long time periods (hundreds of thousands of years) of the Earth's climate record are being cataloged through the interpretation of tree rings, ice cores, and ocean sediments. Techniques are used to merge the historical and the more recent records to begin to draw a connected picture of how the climate has changed over centuries and millennia.

During the most recent 20 years, scientific knowledge and observation systems have provided us the first opportunity to monitor, evaluate, and recognize climate trends, variations and change on a variety of time scales, such as seasonal to interannual, decadal to centennial, and longer, as well as over large regions and globally. Modern land, ocean, airborne, and space-based observing systems can provide the quality climate records and observations needed to monitor today's local, regional, national, and global weather to the degree of precision and accuracy required to instill confidence in the models that will evaluate and forecast future climate trends and changes.

Current NOAA Climate Monitoring Efforts

Climate researchers worldwide are actively working to better understand and answer the question, "Why and how does climate change"? Mechanisms that cause the climate to change are referred to as "forcings." Physical processes that accelerate or decelerate changes produced by a given forcing mechanism are called "feedbacks." Intensive research into models and simulations that can accurately describe forcing and feedback mechanisms is being conducted to help answer the "Why and How." These models require a large volume of current and historical climate quality observations and information.

The mechanisms and the interrelationship between the atmosphere, oceans, and land processes are not well understood. However, in large part due to in-ocean and satellite monitoring systems over the past 20 years, observations, monitoring, and analysis have revealed the link between what occurs in the Pacific (El Niño and La Niña), Atlantic (North Atlantic Oscillation), and the Arctic (Arctic Oscillation) Oceans and the weather patterns over the United States. Models are being developed to forecast the impact of these distant phenomena on regions in the United States. Researchers use field experiments with a complex suite of observing systems (e.g., ships, buoys, aircraft, satellites, etc.) to achieve saturation coverage of a limited geographical area in order to intensively study a particular forcing or feedback mechanism. For example, the Tropical Ocean Global Atmospheres/Coupled Ocean Atmosphere Response Experiment (TOGA/COARE), started in the early 1990s in the "warm pool" of the equatorial western Pacific Ocean to examine the role of the El Niño-Southern Oscillation phenomena. During an intense and concentrated four month observation period, ships, aircraft, and satellites collected thousands of observations, that have been analyzed and studied by more than 100 scientists from over two dozen countries. Analyses of these observations have led to a better understanding of the ocean-atmosphere coupling in the western Pacific. This research has improved predictions of El Niño events and associated regional and global weather and economic impacts far from the equatorial western Pacific region.

Another example of large scale monitoring is the Global Water and Energy Cycle Experiment (GEWEX) involving many thousands of observations around the world and across the United States. GEWEX is an on-going program with three areas of emphasis: 1) generation and exploration of global water and energy data sets using polar and geostationary satellite data, 2) regional hydrometeorological experiments in a variety of continental river basins, and 3) numerical modeling, particularly at very high resolution. Application of observations and the associated research in these areas have led to a reduction of uncertainty in water vapor and cloud feedback processes, improved regional modeling of precipitation and land surface feedback processes, and improved cloud resolving models. The NNDCs are charged with the stewardship of the TOGA/COARE and GEWEX data, ensuring data availability and access by all users in perpetuity.

Climate Observations: Yesterday, Today and Tomorrow

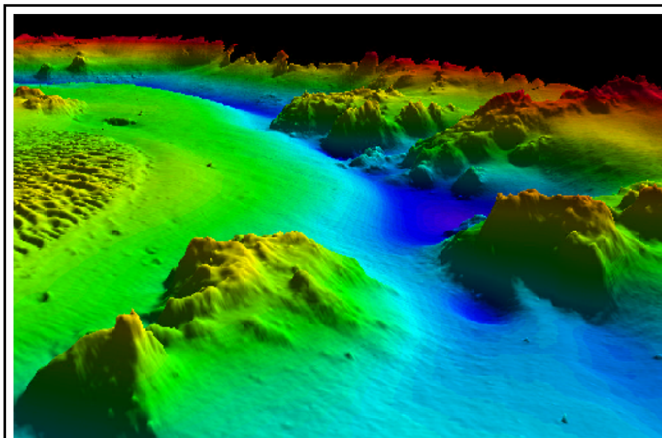
The 20th century demonstrated the growing need for and utility of observations, particularly in support of economic activities. New observing systems were deployed to support specific objectives, such as the arrival of the era of aviation, and more recently the management of finite energy and water resources. Technology provided the means to use satellites, ocean buoys, and Doppler weather radars. The use of the information from these observing systems now support every sector of the economy, help to monitor the status of environmentally sensitive and damaged areas, such as estuaries, rivers, and deserts. They also contribute to evaluating and monitoring health risks. During the last 100 years, the use of fossil fuels has dramatically increased, a consequence of the industrial revolution. There has also been an unprecedented worldwide harvesting (without replacement) of large tracts of forests. We are now conscious of the potential impacts of humankind's activities on climate change.

The 21st century will demand even more climate-related information and analyses, now that we possess the technologies to collect and process large volumes of data and information. The challenge will be implementing and maintaining an integrated climate observing system nationally and globally, including the long-term preservation of those data collections. Climate-driven observing systems will provide the level of climate quality observations and information leading to increased knowledge and understanding of climate trends, variations, and change. These data and improved models directly support the President's CCRI and the CCSP. United States observing systems are an integral component of the Global Climate Observing System (GCOS), which is an international effort to coordinate, integrate, and use climate-related observations to monitor, evaluate, and forecast climate trends and change.

A key element to successful climate monitoring starts with quality climate databases, documentation of the observing system and data, and access to the observations and information. The challenge facing the NNDCs is not only ingesting and processing the data, but the convenient and timely access to data and information. Millions of paper pages and thousands of feet of microfilm/microfiche of recorded instrument measurements and other information dating back hundreds of years are currently under the stewardship of the NOAA NCDC. Prior to the invention of instruments and written records, the climate history of the world (referred to as paleoclimatology) was captured by nature's recorders, such as tree rings, ice cores, coral skeletons, lake and sea floor sediments, and other non-written sources. Over the past 50+ years many observations have been stored in digital form. Today, the three NNDCs manage over 1.4 petabytes (PB) of digital data, as well as millions of paper and microfilm records. Over the next ten years new satellites and improved weather radars will dramatically increase by several orders of magnitude the volume of data and information. Meeting the challenges presented by the "proliferation and complexity" of data and information and the associated issue of scientific data stewardship are further discussed in Section III, subsections C and E of this report.

Digital databases, such as wind speed and direction, precipitation, temperature, and pressure are far more useful than paper and microfilm records to support many disciplines beyond the research community, such as engineering, construction, economic interests, insurance industry, passive energy (solar, wind) enterprises, and many others.

The Climate Database Modernization Program (CDMP) addresses access and utilization issues. The CDMP goal is to make paper/film non-digital historical climate data digitally accessible online via the Internet. Access to historical climate information will be a combination of optically scanned digital images of records and digitized (manually keyed) observations. Thirty million documents have been imaged and many thousands of observations manually keyed or digitized from shipping records, America's military forts, major U.S. cities, lighthouses, weather ships, and other sources. One major data set nearing completion is the daily climate observations from over 5,000 stations for the period 1895-1948 (obtained from nearly 50,000 microfiche and requiring about two billion keystrokes). Some of these climate data now available online include: hourly surface observations (from 1900 to the present); sea level; marine observations (late 1800s); and daily observations (1820s to the present). Station history and information on the observing systems cover a period back to the 1800s when the first observing networks were established. Five major



Gridded multibeam depth data from Portsmouth Harbor, New Hampshire.

serial climate publications documenting the climate of America from the 1870s to the present have been imaged and made available online.

Climate Monitoring: NOAA's Ocean Data

The oceans are the great regulator of climate on the decadal- to centennial-time scales. Ocean observations are not as extensive as land observations, nor as well structured and organized as weather observing systems. Therefore, they are more difficult to collect and archive. Ocean data, in many formats, are collected during numerous, often unrelated, expeditions conducted by many countries and different oceanographic institutions. NOAA NODC has oversight for two closely related projects that exemplify the capabilities described in the previous section: the Global Oceanographic Data Archaeology and Rescue (GODAR) Project, which is sponsored by the Intergovernmental Oceanographic Commission (IOC), and the World Ocean Database Project. These two projects have added more than three million digitized ocean temperature profiles to the databases, which are being accessed by the international research community studying the role of the ocean in the Earth's climate system.

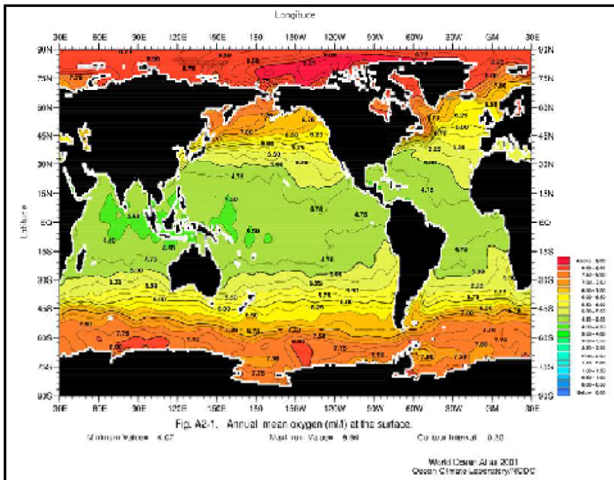
The goal of GODAR is to integrate the world coastal and marine data record into computer-accessible, standardized world ocean databases. Since much of the world oceanographic data record exists either in written manuscript form, or in non-standardized computerized (digital) format, the GODAR process involves data searches (data mining) to locate relevant data sets, data rescue to salvage data from deteriorating media, digitizing data into standardized world ocean databases, and transformation of extant digitized data into standardized world ocean databases. The result of this work has been a substantial increase in the amount of historical oceanographic data available to the ocean and climate research communities.

NOAA's NODC leads the World Ocean Database Project. *World Ocean Database 2001*(WOD01) is a global, comprehensive, integrated, scientifically quality-controlled database that is completely documented and available online and on CD-ROM. Temperature, historical and modern salinity, nutrient, chlorophyll, and plankton data are among the observations included in this database. Chemical and biological data allow researchers to study the Earth's carbon cycle, as well as ecosystem response to climate change. WOD01 is used by researchers throughout the world for climate system diagnostic studies and in numerical simulation studies of the Earth's climate system. The complexity of sampling and monitoring the ocean increases as scientists seek to better understand and evaluate the ocean's role in influencing climate, particularly the part it plays in the global carbon cycle.

Climate Monitoring: NOAA's Geophysical Data

The NOAA NGDC manages land and marine geology, geophysics, and solar-terrestrial data. Discipline-specific areas of collection include bathymetry, topography, geomagnetism, snow and ice, ecosystems, space environment, and solar and interplanetary phenomena. The quality data, in both analog and digital format, are used regularly in climate monitoring and research. The NGDC provides a comprehensive set of global ocean base-data, such as coastal relief grids, hydrographic surveys, and track line/multi-beam bathymetric data that are essential to studying the ocean-climate interface. The NGDC archives and disseminates multi-sensor, remote sensing data from the DMSP platforms. Like the NODC and the NCDC, more of the digital data are becoming available online in easily accessible formats.

NOAA's Climate Monitoring Challenges



This map shows the distribution of the world's oceans' dissolved oxygen concentration at 500 meters depth. It is based on historical and modern oceanographic data collected from ships from many countries, and appears in NOAA's World Ocean Atlas 2001. Understanding short and long-term oxygen changes and their relation to other parameters in the ocean such as temperature, salinity, carbon, nutrients, and plankton provide an insight into the oceanic response to global climate changes.

Several challenges must be addressed in the pursuit and achievement of climate monitoring goals and objectives. Intergovernmental Panel on Climate Change (IPCC) Reports, National Research Council (NRC) Report (1999)[21] and NRC Report (2001)[22], NOAA Science Advisory Board Report[23], and other studies clearly identify deficiencies and recommendations for meeting the challenges of climate monitoring and assessments. A few of the most pressing issues include: implementing climate quality observing systems; the ability to digitally ingest in real-time the current and proposed wide array and volume of observations from *in-situ* (land and ocean), airborne, and satellite observing systems; quality control processing; network monitoring in real-time; "data mining" of key parameters; providing immediate availability (access), "data fusion" (merging) of key parameters from different systems (e.g., satellites, radars, ocean, and land surface); rehabilitating historical databases and data sets; and improved modeling techniques. Part of this effort to create a more comprehensive historical climate perspective includes an active paleoclimatology program. This program will incorporate extremely long periods of record dating back hundreds of millennia. Major progress has been made but much remains to be done.

The Comprehensive Large Array-data Storage System (CLASS) project is providing an integrated approach to designing and implementing the data management system (ingest, processing, access, and archive) required to meet the new observing systems planned for deployment early in the 21st century. e-commerce and e-business techniques and technologies will be employed to meet the demand for rapid and convenient access to past, present, and future observations, data, and information.

The ten climate monitoring principles described by the NRC[21] are being used to guide the design, deployment, and life cycle management of the NOAA-managed U.S. Climate Reference Network (USCRN). The USCRN is the first U.S. observing system being built with the primary purpose of providing climate quality measurements. The fully deployed network of USCRN stations will be able to explain at least to the 95 percent level the variance in surface temperature and precipitation on the national and regional scales. The USCRN climate quality observations avoid the time dependent biases typically experienced with other surface observing networks. The USCRN will be the Nation's benchmark network, providing a standard to which satellite, weather radar, and other surface systems (e.g., ASOS and COOP) observations can be validated and verified. In essence, the USCRN will provide the means to enhance the quality and confidence in other observations, as well as contribute to rehabilitating existing historical databases and data sets. This will produce a significant increase in the volume of climate quality data and information that can be used in assessing past climate trends and change, as well as contribute to the present and future climate monitoring, evaluation, and forecast tasks.

Real-time network monitoring of observing systems is fundamental to ensuring the quality of observations and the subsequent databases and data sets. One of the shortcomings of past and current observing systems is that typically errors in the data are not caught until well after the data have been archived. Periodic re-analysis of historical files routinely identify time dependent and other quality data issues. During the past two years, the NOAA NCDC has systematically developed network monitoring procedures for some observing networks. When data quality issues are discovered, the system manager is notified. A key performance measure regarding the quality of the USCRN data is the use of sophisticated, automated software that monitors each sensor, station, and the entire network on a daily basis.

NOAA Climate Monitoring Data Management: Next Steps

Climate monitoring, evaluation, and forecasting are critical to economic sustainability and environmental stewardship, as well as planning and responding to the quality of life changes that society will encounter in the 21st century and beyond.

The deployment of a new generation of satellites over the next ten years [NASA's Earth Observing System (EOS), Next Generation GOES, joint (DoD/NASA/NOAA) National Polar-orbiting Operational Environmental Satellite System (NPOESS)] and the enhancement of the operational NEXRAD (dual polarization and phased array) present major data management challenges to NOAA.

Today, data and information are not easily accessible or easily integrated to provide a comprehensive and multi-disciplined picture of climate trends and change. Scientists and decision-makers will need to rapidly access and use climate data and records dating back decades and centuries in order to create a total, inclusive portrait of the Earth's dynamic climate system. If the Nation continues to promote the programs described above and embraces new programs and emerging technologies, the requisite knowledge and understanding will emerge from the research community. This work will then produce useful and informative products and services that leaders and decision makers can use with a high degree of confidence when formulating and implementing policies and business decisions.

The Scientific Data Stewardship (SDS) approach to data management can be applied to climate monitoring. Studies can be undertaken to document and understand climate trends, variability, and change. A fuller understanding of past droughts, floods, heat waves, and cold spells, to mention a few issues impacting humans, will lead to better predictions to allow better management of their impacts.

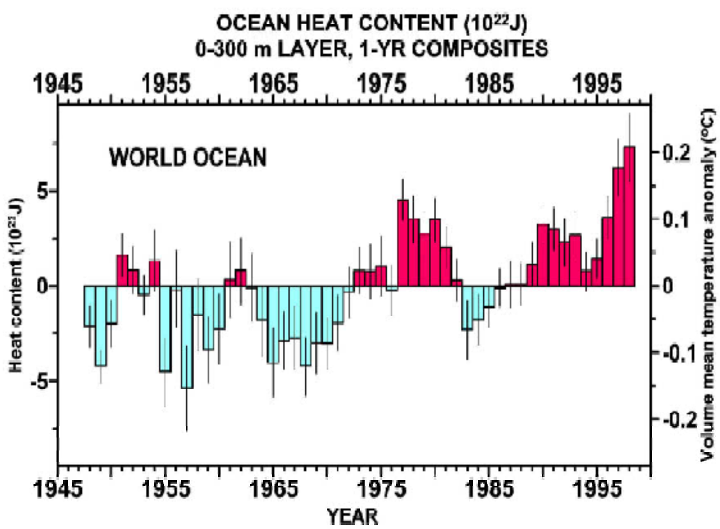
There is increased demand for finer resolution spatial coverage of environmental observations and for parameters not feasible in the past, such as from remote sensing systems. Increased demand is coincident with more data available online for users. Experience shows that when data can be accessed online by users via the Internet, the amount of data provided to users increases by several orders of magnitude of the data ingested. For small data streams, such as hourly weather observations, the amount of data serviced from the archives exceed by 10,000 times the amount ingested per month. Data serviced from the POES exceed by as much as 100 times the volume of POES data ingested daily.

The NRC Report[22] on climate services underscores the matters at hand: "The major challenges involve data management; the storage, indexing, referencing, and retrieval of data; and the ability to combine, dissect, and query information." Fundamental to success are improvements in data management techniques, implementation of advanced information technology, development of automated network monitoring and quality control processing systems, and the utilization and training of employees with new skills.

NOAA has responded with a variety of programs in an attempt to meet the Nation's climate monitoring and assessment demands of the 21st century. A revised NOAA Strategic Plan has been developed in response to the Nation's need for environmental and economic support and information.[24] This strategic plan will provide the guidance to the NOAA organization regarding formulation and execution of plans and activities to provide results for the American taxpayer. It will be regularly reviewed and updated. In partnership with continued support from the Administration and Congress, NOAA will be able to address these climate monitoring and other data management challenges and deliver meaningful and informative supporting products and services to the Nation.

E. Ocean Data Management

NOAA's Ocean Data Legacy



NOAA scientists determined that the world ocean has warmed significantly during the past 40 years. The largest warming has occurred in the upper 300 meters of the world ocean on average a little over 0.5 degrees Fahrenheit. These findings were made by using 5.1 million temperature profiles from around the world to quantify the variability of the heat content (mean temperature) of the world ocean from the surface through 3,000 meter depth for the period 1948 to 1996. The Atlantic, Indian, and Pacific Ocean basins were examined.

Because the Earth is roughly spherical and is heated by hydrothermal energy released by the Sun, the equatorial regions closest to the Sun are warmer than the polar regions located farthest from the Sun. This simple fact sets the stage for many of the tremendous physical oceanographic processes that create both surface and submerged large-scale ocean currents, drive atmospheric weather conditions, support biological oceanographic processes, play a role in long-term climate and sea-level change, and profoundly affect human society. The world oceanographic research community has studied these processes intensively for over a century, and has collected a vast data record to support their research. Since NOAA's founding in 1970, it has played a major role both in on-going oceanographic research, and in the stewardship of data generated throughout the history of oceanographic research. NOAA's NESDIS is responsible for the stewardship of oceanographic data. Its mission is "to provide and ensure timely access to global environmental data from satellites and other sources to promote, protect, and enhance the Nation's economy, security, environment, and quality of life." To fulfill its responsibility for oceanographic data, NESDIS operates the NNDCs and the new NCDDC. Each center plays a leading role in the rescue, archival, stewardship, and accessibility of the historical oceanographic data record.

Key NOAA Services supporting Ocean Data: Data Access

Access to data is an important part of all data management and is being addressed within NOAA by use of both traditional and progressive data management techniques that allow for the discovery, access and retrieval of ocean data. These traditional capabilities include the ability to order both online and off-line NOAA data via the Internet in the traditional storage and delivery formats. Progressive data management techniques are being employed to enable a virtual portal from where ocean data, including coastal data, may be discovered, accessed and retrieved from distributed sources including non-NOAA repositories. This architecture provides users with capabilities not traditionally available to allow format, unit, projection, and datum translations.

Data discovery is an important part of data access. Within ocean data management this is being addressed by providing a catalog service that is dependent on metadata. Search capabilities then use this catalog and can be implemented to search on any portion of the metadata record including full text searches.

II. Spectrum of NOAA Environmental Data Services: Internet Sites

National Oceanic and Atmospheric Administration (NOAA)
http://www.noaa.gov

Commerce and Transportation:

NOS Office of Coastal Survey Nautical Charting Program
http://www.nauticalcharts.noaa.gov

NOAA/Navy National Ice Center (NIC) Coverage Charts and Analyses
http://www.natice.noaa.gov/

Hydrographic Surveys - National Survey Plan
http://chartmaker.ncd.noaa.gov/staff/nsp/NSPFinal.pdf

NOS National Spatial Reference System
http://www.geodesy.noaa.gov/INFO/OnePagers/One-Pager_NSRS.pdf

National Geodetic Survey (NGS) - Continuously Operating Reference Stations (CORS):
http://www.geodesy.noaa.gov/CORS/cors-data.html

NOS Physical Oceanographic Real-Time System® (PORTS®)
http://www.tidesandcurrents.noaa.gov/d_ports.shtml

NWS Marine Observation Network (MON)
http://www.ndbc.noaa.gov/index.shtml

National Water Level Observing Network (NWLON)
http://www.tidesandcurrents.noaa.gov/data_res.html

NWS Automated Surface Observing System (ASOS)
http://www.nws.noaa.gov/asos/index.html
http://www.srh.weather.gov/jetstream/remote/asos.htm

NWS Cooperative Observer Network (COOP)
http://www.nws.noaa.gov/om/coop/

NWS Next Generation Weather Radar (NEXRAD)
http://www.nssl.noaa.gov/researchitems/radar.shtml
http://weather.noaa.gov/radar/national.html
http://www.srh.weather.gov/jetstream/remote/doppler.htm

NWS Radiosonde Network
http://www.ua.nws.noaa.gov/
http://www.publicaffairs.noaa.gov/budget02/nws_sonde.html
http://www.srh.weather.gov/jetstream/remote/ua.htm
NOAA Profiler Network (NPN)
http://www.profiler.noaa.gov/jsp/index.jsp

Department of Transportation FHWA FORETELL program
http://ops.fhwa.dot.gov/Weather/FORETELL/Fortell.pdf

Nautical charts and hydrographic surveys
http://www.nauticalcharts.noaa.gov
http://www.ngdc.noaa.gov

Hazards:

Environmental Sensitivity Indexes
http://response.restoration.noaa.gov

Oil spill responder information
http://response.restoration.noaa.gov