CHAPTER 28: MODERNIZING OCEAN DATA AND INFORMATION SYSTEMS

Ocean and coastal research and observational activities are generating new data at ever-increasing rates—data that must eventually be analyzed, distributed, and stored. The nation's ocean and coastal data management systems should be modernized and integrated to promote interdisciplinary studies and provide useful information products for policy makers, resource managers, and the general public. Better interagency planning is needed to coordinate federal data management. An information management and communications program will help produce operational ocean and coastal forecasts and disseminate information products relevant to national, regional, and local needs. Ultimately, the goal should be to transition all environmental data archiving, assimilation, modeling, and information systems, which are currently divided by environmental sectors, into a fully integrated Earth environmental data system.

TURNING OCEANS OF DATA INTO USEFUL PRODUCTS

Ocean and coastal data are essential for understanding marine processes and resources. They are the foundation for the science-based information on which resource managers depend. Previous chapters have provided ample evidence of the importance of data from ocean, coastal, and watershed observations; but processing these data, and converting them into information products useful to a broad community of end users, remains a huge challenge.

For the purpose of this discussion, *data* are defined as direct measurements collected during scientific research, observing, monitoring, exploration, or other marine operations. *Information*, on the other hand, includes both *synthesized products* developed through analyses of original data using statistical methods, interpolations, extrapolations, and model simulations, and *interpreted products* developed through incorporation of data and synthesized products with additional information that provides spatial, temporal, or issue-based context.

There are two major challenges facing data managers today: the exponentially growing volume of data, which continually strains data ingestion, storage, and assimilation capabilities; and the need for timely accessibility of these data to the user community in a variety of useful formats. Meeting these challenges will require a concerted effort to integrate and modernize the current management system. The ultimate goal of improved data management should be to effectively store, access, integrate, and utilize a wide and disparate range of data needed to better understand the environment and to translate and deliver scientific results and information products in a timely way.

REVIEWING THE DATA MANAGEMENT STRUCTURE

Data centers throughout the nation collect and analyze environmental data and information. Because these centers often operate in isolation, users who need to gather and integrate data from multiple sources can face an inefficient and lengthy process.

Types of Data Centers

National Civilian Data Centers

The national data centers that archive and distribute environmental data have been evolving since the late 1950s. Federal science agencies maintain ten national data centers, some with regional extensions (Table 28.1). These centers collect, archive, and provide access to an assortment of publicly available data sets streaming in from local, regional, and global environmental observing systems. Nine of the centers are run by federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), National Aeronautics and Space Administration (NASA), and U.S. Department of Energy. The remaining center is housed at Columbia University and is sponsored by twenty-two federal and nonfederal organizations.

Each federal data center collects and archives complementary data and information sets. Yet for the most part, these centers are disconnected from each other, and attempting to gather and integrate data from several centers can be a time-consuming and sometimes impossible task due to differences in storage formats and computer software. Ever-increasing amounts of incoming data will only exacerbate this untenable situation, impeding the creation and dissemination of critical information products.

Stages in Data and Information Management

- *Collection*—gathering data from a range of sources, including observing systems and field research investigations.
- *Ingestion*—receiving data at data centers and processing it for entry into the archives.
- *Quality control*—determining the reliability of data received.
- *Archiving and maintenance*—standardizing formats, and establishing databases and security at repository centers.
- *Rescue and conversion*—identifying and reformatting historical data for placement into the archives.
- *Access and Distribution*—making data and information products available to end users.
- *Modeling*—using data in numerical computer models to describe systems, theories, and phenomena related to natural processes.
- *Assimilation and Data Fusion*—assembling and blending data, and combining them with models in optimal ways for operational and research purposes.

Useful Terms

- *Metadata*—information about the origin and attributes of data that allows users to find, understand, process, and reuse data and data products.
- *Visualization tools*—methods of visually displaying data, such as visualization theaters, computer displays, and maps and charts.
- *Communication networks*—telecommunications infrastructure that transfers data from observing systems to data centers, and from these centers to end users.

Distributed Active Archive Centers

NASA operates eight Distributed Active Archive Centers (DAACs) that are separate from the civilian data centers. The primary objectives of these DAACs are to focus on data from specific missions and experiments, not long-term stewardship of data. Implementation of the DAACs has been costly, and they have not yet fulfilled their potential.

NASA is now trying to organize the DAACs into a federation of databases managed by academia and industry, possibly transitioning away from the structure of the current centers. As part of this new organizational structure, and in an attempt to achieve long-term data storage and coordination, NASA data are supposed to be transferred to NOAA or USGS within fifteen years after their collection.

Table 28.1. Current National Civilian and Military Data Centers
Listed below are the existing federal data centers along with their sponsoring agencies and scientific specialties.

Center	Agency	Specialty
National Data Centers		
Carbon Dioxide Information Analysis Center (CDIAC)	U.S. Department of Energy	Atmospheric trace gases, global carbon cycle, solar and atmospheric radiation
Center for International Earth Science Information Network (CIESIN)	Columbia University (supported by contracts from 22 nonfederal and federal agencies)	Agriculture, biodiversity, ecosystems, world resources, population, environmental assessment and health, land use and land cover change
Earth Resources Observation Systems (EROS) Data Center (EDC)	U.S. Geological Survey (USGS)	Cartographic and land remote-sensing data products
National Earthquake Information Center (NEIC)	USGS	Earthquake information, seismograms
National Climatic Data Center (NCDC)	National Oceanic and Atmospheric Administration (NOAA)	Climate, meteorology, alpine environments, ocean–atmosphere interactions, vegetation, paleoclimatology
National Geophysical Data Center (NGDC)	NOAA	Bathymetry, topography, geomagnetism, habitat, hazards, marine geophysics
National Oceanographic Data Center (NODC)	NOAA	Physical, chemical, and biological oceanographic data
National Snow and Ice Data Center (NSIDC)	NOAA	Snow, land ice, sea ice, atmosphere, biosphere, hydrosphere
National Coastal Data Development Center	University of Colorado (under cooperative agreement with NOAA)	Data relevant to coastal managers
National Space Science Data Center (NSSDC)	National Aeronautics and Space Administration (NASA)	Astronomy, astrophysics, solar and space physics, lunar and planetary science
Distributed Active Archive Centers (DAACs)		
Oak Ridge National Laboratory (ORNL) DAAC	NASA	Terrestrial biogeochemistry, ecosystem dynamics
Socioeconomic Data and Applications Center (SEDAC)	NASA	Population and administrative boundaries
Land Processes (EDC) DAAC	NASA	Land remote-sensing imagery, elevation, land cover
National Snow and Ice Data Center (NSIDC) DAAC	NASA	Sea ice, snow cover, ice sheet data, brightness, temperature, polar atmosphere
Goddard Space Flight Center (GSFC) DAAC	NASA	Ocean color, hydrology and precipitation, land biosphere, atmospheric dynamics, and chemistry
Langley Research Center (LaRC) DAAC	NASA	Radiation budget, clouds, aerosols, and tropospheric chemistry
Physical Oceanography (PO) DAAC	NASA	Atmospheric moisture, climatology, heat flux, ice, ocean wind, sea surface height, temperature
Alaska Synthetic Aperture Radar (SAR) Facility DAAC	NASA	Sea ice, polar processes
Military Data Centers of Particular Importance to Ocean-related Issues		
Naval Oceanographic Office	U.S. Navy	Bathymetry, hydrography, oceanography
Fleet Numerical Meteorology and Oceanography Center	U.S. Navy	Atmosphere and oceans

Source (except military centers): National Research Council. *Government Data Centers: Meeting Increasing Demand*. Washington, DC: National Academy Press, 2003.

Military Data Centers

Several military data centers exist in addition to the civilian centers. Of particular importance are the U.S. Department of Defense assets at the Naval Oceanographic Office and the U.S. Navy's centers for ocean observation and prediction, which include the Fleet Numerical Meteorology and Oceanography Center, the Naval Oceanographic Office, and the Naval Ice Center. These centers are integrated with the civilian sector's national data centers through memoranda of agreement, primarily with NOAA, NASA, the Department of Energy, and the National Science Foundation (NSF). The purpose is to incorporate certain classified data into civilian research and operational products while retaining their confidentiality.

Other Specialized Data Centers

Fifteen discipline-based World Data Centers exist in the United States that collect and archive data related to atmospheric trace gases, glaciology, human interactions in the environment, marine geology and geophysics, meteorology, oceanography, paleoclimatology, remotely sensed land data, seismology, and solar-terrestrial physics. Individual states also operate data centers associated with certain state environmental offices, such as weather or geological offices. Independent specialized data collections have also been assembled by interagency groups, university and research centers, and consortia in various fields of science.

Ocean and Coastal Data

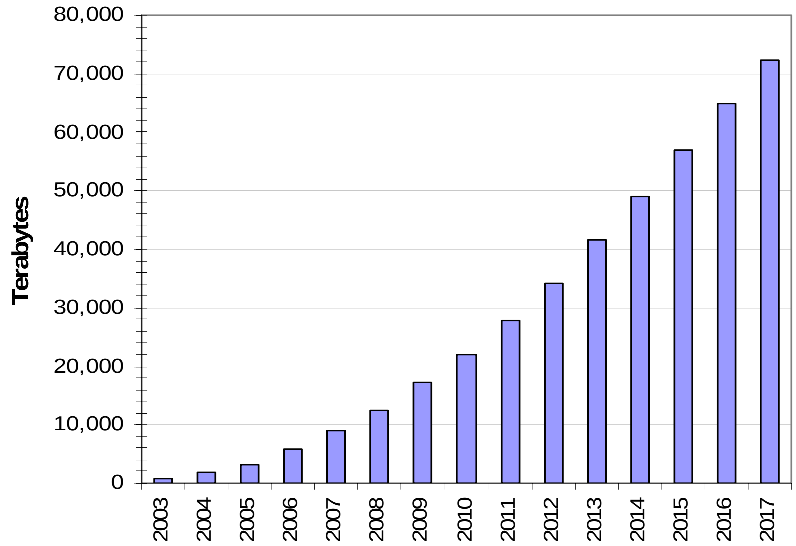
Ocean, coastal, and watershed data are primarily located in NOAA, NASA, USGS, the U.S. Environmental Protection Agency, and the Navy. NOAA has the unique mission of archiving environmental data, with a special focus on ocean and coastal data, and making it accessible to support management and economic decisions and ecosystem-based research. NOAA carries out this mission through its national data centers (five of the ten listed above), which jointly manage large collections of atmospheric, oceanographic, and geophysical data. Despite the fact that these five centers are co-located within NOAA, they function independently of each other, and it remains difficult for users to acquire and integrate data in a seamless manner. Other agencies are also experiencing problems with incorporating, storing, and distributing large amounts of environmental data. For example, USGS has struggled with the large volumes of Landsat satellite data which have historically been very helpful in ocean and coastal research and management activities.

Coping with the Flood of Incoming Data

Throughout the 1990s and into this century, all of the national military and civilian data centers have experienced tremendous growth in the inflow and archiving of data. This growth is expected to continue; NOAA data holdings are projected to grow by a factor of 100 between 2002 and 2017 (Figure 28.2).[1] This projection may actually be an underestimate if currently envisioned automated data collection systems come on-line. The civilian data centers make data available to support operational products and forecasts and to fill specific requests. During the 1990s, NOAA's on-line data requests grew to 4 million a year (an average of 11,000 per day), while off-line requests doubled to a quarter of a million (Figure 28.3). Although many users increasingly rely on electronic access, only 4 percent of NOAA's digital data archive is currently available on-line and many of NOAA's historical data sets have yet to be converted to digital form.[2]

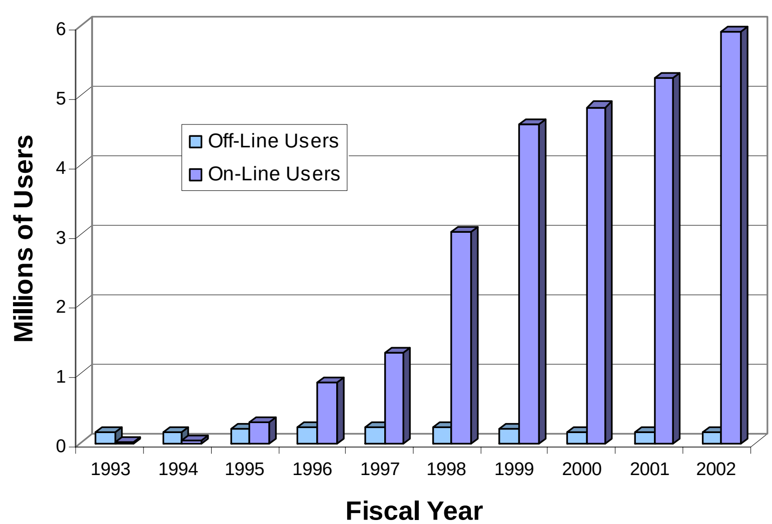
Ongoing improvements to ocean databases have substantially increased the amount of available data and have dramatically improved accessibility. However, data collection and information needs continue to outpace archiving and assimilation capabilities.

Figure 28.2. The Flood of Ocean and Coastal Data into NOAA



Between 2002 and 2017, NOAA's data holdings are expected to grow by a factor of 100, to a value of 74 million gigabytes. (One gigabyte roughly equals one billion bytes; one terabyte equals about one thousand gigabytes.)
Source: National Oceanic and Atmospheric Administration. *The Nation's Environmental Data: Treasures at Risk: A Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. Washington, DC: U.S. Department of Commerce, 2001.

Figure 28.3. The Growing Demand for Ocean Data



On-line users are requesting increasing amounts of environmental data and information from NOAA each year. Improved data handling practices are needed to address the growing volume of requests.
Source: National Oceanic and Atmospheric Administration. *The Nation's Environmental Data: Treasures at Risk: A Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems.* Washington, DC: U.S. Department of Commerce, 2001.

Reinventing Data and Information Management

Several improvements can help make the national system for storing and distributing ocean and coastal data more effective. Agencies tasked with collecting, archiving, assimilating, and disseminating data need to increase their cooperation and coordination and provide faster, easier, and more unified access to raw and processed data. In return, scientists and other data generators need to feed valuable, high quality data into the national system in a timely way.

Interagency Planning

Growing observational capabilities, improved numerical models of the world, and formal methods for linking data and models now permit scientists to study ecosystems with an unprecedented degree of realism. The impact of these developments on the understanding of oceanic processes pervades all disciplines and fuels cross-disciplinary links between physical, biological, and chemical oceanography, marine geology and geophysics, and atmospheric sciences.

Nevertheless, inadequate information technology infrastructure inhibits progress. Continuing efforts to establish modeling and data assimilation nodes within the National Ocean Partnership Program agencies provide just one example of a high-priority activity where infrastructure limitations are acute. Topics of particular concern include:

Data Incorporation—Scientists and managers need to combine data from disparate sources to produce information products, often in real time. As computer software and hardware technologies evolve, data stored in older formats need to be upgraded. In particular, enormous archives of historical data exist only in nondigital formats. Differences in data protocols also remain among scientific fields; physical and biological variables are measured using very different parameters. New methods are needed to incorporate biological data into ocean and coastal information products.

Computer Hardware—Ocean scientists are expected to require 10 to 1,000 times the current hardware capacity over the next five to ten years, with the most critical bottlenecks occurring in the availability of computer processing power, memory and mass-storage capacity, and communications network bandwidth. [3] Many oceanographic models have grown in computational size to the point that they require dedicated, long-term computing that exceeds the time available on computers currently used for most medium- and large-scale ocean projects.

Software and Modeling—Software challenges include the need to redesign models and methods to assimilate new data sources and improve visualization techniques to deal effectively with increasing volumes of observations and model outputs. There is a need throughout the ocean science community for well-designed, documented, and tested models of all types. Models of living systems lag significantly behind those related to physical variables; the capacity to run simulations of organisms, populations, and ultimately ecosystems, is currently not available.

Human Resources—In the early days of collecting and storing environmental data in digital formats, many of the technical staff were environmental scientists who gained experience through on-the-job training and trial and error. By the mid-1980s, this type of education was wholly inadequate to meet the ever-increasing complexity of computer hardware and software systems, and the volumes of digitized data being collected and archived. As technical requirements grew, the federal government fell far behind academia and the private sector in attracting and retaining highly trained experts, particularly because government pay scales for information technology specialists were well below those of the private sector. This scenario continues today. A strategy is needed for attracting and retaining highly trained technical staff in the federal government.

Meeting User Needs—Data and information must be available to a wide range of users, from scientists looking for raw data, to the individual interested in forecasts and other easily understandable information products. User needs should be determined at national, regional, and local levels. The regional ocean information programs, discussed in Chapter 5, will be an essential link to user communities when deciding on priorities.

An interagency group, dedicated to ocean data and information planning, is needed to enhance coordination, effectively use existing resources for joint projects, schedule future software and hardware acquisitions and upgrades, and oversee strategic funding. Most importantly, this entity will create and oversee implementation of an interagency plan to improve access to data at the national data centers, DAACs, and other discipline-based centers. The plan will need to be appropriately integrated with other national and international data management plans, including those for the Integrated Ocean Observing System (IOOS) and Global Ocean Observing System.

This coordination must extend beyond ocean data. The ocean community needs to take a leading role in broader environmental data planning efforts, such as the federal cyber infrastructure initiative. An interagency planning group could also coordinate the development of a viable, long-term strategy for partnering with the private sector to enhance environmental data and information management capabilities. This organization should not have an operational role, but instead should be responsible solely for interagency planning and coordination, similar to the role of Ocean.US for the IOOS.

Recommendation 28–1. Congress should amend the National Oceanographic Partnership Act to establish and fund Ocean.IT as the lead federal interagency planning organization for ocean and coastal data and information management. Ocean.IT should consist of representatives from all federal agencies involved in ocean data and information management, be supported by a small office, and report to the National Ocean Council's Committee on Ocean Science, Education, Technology, and Operations.

Ocean.IT should:

- *create an interagency plan to improve coordination between the existing data centers and integrate ocean and coastal data from different agencies and from the academic and private sectors.*
- *set priorities for archiving historical and nondigital data.*
- *coordinate shared resources and the acquisition of new hardware for use by the ocean sciences community.*
- *work with existing supercomputer centers to articulate and negotiate for ocean science needs.*
- *assess federal agency software needs and initiate interagency programs to create high-priority applications, such as new modeling programs.*
- *coordinate federal agency efforts to attract information technology expertise into the ocean sciences community.*
- *communicate with regional, state, and local organizations, including the regional ocean information programs, to determine user needs and feed this information back into agency activities.*

Access to Data and Information

There are two distinct types of data sought by users. Scientists are generally interested in calibrated, long-term time series of basic data that can be used to study topics such as atmospheric composition, ecosystem change, carbon cycles in the environment, the human dimensions of climate change, and the global water cycle. At the other end of the spectrum, the general public is most often interested in outcomes based on data analysis, such as forecasts and models, and do not wish to see the original data. Users seeking information products include commercial users, policy makers, and educators seeking information to develop curricula and class materials.

Information Products and Forecasts

Compared to a few decades ago, an impressive array of data and information products for forecasting ocean and coastal conditions is now available from a wide range of sources. A mechanism is now needed to bring these data together, including the enormous amounts of information that will be generated by the national IOOS, and use them to generate and disseminate products beneficial to large and diverse audiences.

At the national level, civilian operational ocean products and forecasts are produced mainly by NOAA's National Weather Service and National Ocean Service. The National Weather Service routinely issues marine and coastal information and forecasts related to meteorological conditions and issues marine warnings, forecasts, and guidance for maritime users. The National Ocean Service's Center for Operational Oceanographic Products and Services also collects and distributes oceanographic observations and predictions related to water levels, tides, and currents.

Military ocean informational products are produced mainly by two offices. The Fleet Numerical Meteorology and Oceanography Center provides weather and oceanographic products, data, and services to the operating and support forces of the Department of Defense. The Naval Oceanographic Office supplies global oceanographic products and generates strategic, operational, and tactical oceanographic and geospatial products to guarantee safe navigation and weapon/sensor performance.

While each of these offices possesses unique resources, infrastructure, and data, a partnership between them could lead to a new generation of ocean and coastal information and forecasts. A national ocean and coastal information management and communications program that builds on the Navy's model for operational oceanography would take advantage of the strengths of both agencies, reduce duplication, and more effectively meet the nation's information needs. This partnership would also allow for the prompt incorporation of classified military data into informational products without publicly releasing the raw data. A NOAA-Navy joint program would rapidly advance U.S. coastal and ocean analyses and forecasting capabilities using all available physical, biological, chemical, and socioeconomic data.

Private-sector involvement in creating ocean analyses and forecast products has matured over the last thirty years through highly successful public–private partnerships. Interactions between private companies and the national ocean and coastal information management and communications program could lead to the production of a wide range of general and tailored forecast and warning products. An interface between national forecasters at the NOAA–Navy program and the regional ocean information programs would also help identify ocean and coastal informational products of particular value at the regional and local levels.

Recommendation 28–2. The National Oceanic and Atmospheric Administration and the U.S. Navy should establish a joint ocean and coastal information management and communications program to generate information products relevant to national, regional, state, and local needs on an operational basis.

This new joint ocean and coastal information management and communications program should:

- *prioritize products and forecasts based on input from the regional ocean information programs, Ocean.IT, Ocean.US, and the National Ocean Council.*
- *base products and forecasts on all available data sources, including satellite and in situ data, and socioeconomic and biological data where applicable.*
- *create a research and development component of the program to generate new models and forecasts in collaboration with Ocean.IT, taking full advantage of the expertise found in academia and the private sector.*
- *develop a variety of dissemination techniques and educate users about access mechanisms, available products, and applications.*

Raw Data

Although many paths exist to access data, there is currently no focal point where users can go to gain access to all available ocean data and information. As a result, the process can be tedious, and the risk of missing key databases high. Interdisciplinary users face even greater challenges when attempting to integrate data sets from different centers. The varied data standards, formats, and metadata that have evolved over time make data exchange complex and unwieldy. Other problems arise when important data sets are kept by individual scientists or institutions, rather than being integrated into national databases.

One area of critical concern, particularly for coastal resource managers, is the integration of coastal data, including maps, charts, and living and non-living resource assessments. The user community is frustrated by the difficulties in accessing coastal geospatial data. Serious concerns continue regarding the timeliness, accuracy, and descriptions associated with coastal data, and the difficulties of integrating data sets from various sources. Coastal managers and researchers still lack a seamless bathymetric/topographic base map and database for the U.S. coast—an essential underpinning for improved understanding of the processes that occur across the land–sea interface. (The integration of maps and charts is also discussed in Chapter 25.)

Several innovative and highly promising interagency efforts to increase data accessibility are underway. The National Virtual Ocean Data System project is a primary example. Funded by the National Ocean Partnership Program, it facilitates seamless access to oceanographic data and data products via the Internet, regardless of data type, location of the storage site, the format in which the data are stored, or the user's visualization tools and level of expertise. The National Virtual Ocean Data System uses OPeNDAP technology that provides machine-to-machine interoperability within a highly distributed environment of heterogeneous data sets. This is similar to other successful Internet-based file sharing systems that allow users to access data (typically music files!) that reside on another individual's computer. The Ocean.US data management plan envisions that the National Virtual Ocean Data System will be implemented to allow access to IOOS data.

Recommendation 28–3. Ocean.IT should work with developers of the National Virtual Ocean Data System and other innovative data management systems to implement a federally-supported system for accessing ocean and coastal data both within and outside the national data centers.

Incorporating Data into the National Data Centers

Academic Research Data

The discussion of the IOOS in Chapter 26 points to the importance of collecting data from stable, long-term, calibrated *in situ* and satellite sensors. However, there is also value in capturing more ephemeral observational data, typically collected as a part of research projects. Recipients of federal research grants and contracts are required by law to submit their data to the appropriate national data center within a specified time period. Most oceanographic data must be submitted to the National Oceanographic Data Center or the National Geophysical Data Center. Oceanographic data arising from international programs must also be submitted, according to policies established by the Intergovernmental Oceanographic Data Exchange program. However, there are wide variations among agencies in their enforcement of these requirements and their tracking of compliance. Research data are often not submitted to national databases for years after a project ends, if ever. Strengthened procedures, both domestically and internationally, are urgently needed to provide for the timely inclusion of all ocean data into data centers, and to ensure full and open access to data collected at taxpayers' expense.

Recommendation 28–4. The Committee on Ocean Science, Education, Technology, and Operations (COSETO) should establish and enforce common requirements and deadlines for investigators to submit data acquired during federally funded ocean research projects.

In establishing these requirements, COSETO should:

- *provide incentives to ensure more timely submission of investigator data to the national centers.*

- *require that a certification of data deposit be supplied to investigators who comply with the new regulations and that this certificate be presented before subsequent federal funding is provided.*

Reviewing Classified Data

A significant proportion of all oceanographic data is collected and archived by the Navy. However, these data are generally classified and not available for access by the larger oceanographic community. In 1995, the MEDEA Special Task Force was created to determine the potential for important environmental research based on classified Navy databases, and to prioritize data for declassification. Opportunities were identified for mutually beneficial collaborations between the civilian and naval ocean sciences communities, and approaches were suggested to realize broader national benefits from public investments in data collection and modeling by the Navy.[4] Increased access to data declassified as a result of the one-time MEDEA initiative has been very useful to the oceanographic community. Both scientists and managers can continue to benefit from ongoing declassification of Navy data, particularly bathymetric data critical to improved ocean modeling.

Recommendation 28–5. The U.S. Navy should periodically review and declassify appropriate naval oceanographic data for access by the civilian science community.

MEETING THE CHALLENGES OF A NEW CENTURY

Looking beyond the data management needs for ocean sciences, the environmental challenges of the 21st century will require access to the full spectrum of environmental data. As a robust ocean observing system is created, and as the nation moves toward integrating ocean, climate, atmospheric, and terrestrial monitoring systems within a comprehensive Earth Observing System, both the volume of data and the need to integrate widely varied datasets will continue to grow. At the same time, historical environmental data must continually be preserved to enable long time-series analyses of natural processes that occur over decades, centuries, and millennia. Revolutionary discoveries about the Earth's environment and the ability to better predict its dynamics will result from the use of diverse, long-term, integrated data sets.

Critical improvements in the environmental data management infrastructure at the federal level must be made today and sustained into the future to realize the full benefits of an integrated system. Numerous valuable studies, pilot projects, recommendations, and strategies for improved management of environmental data have been produced over the years. However, the integration of existing environmental data is continually impeded by the lack of a unified interagency strategy and a national financial commitment to a modern, integrated data management system.

Recommendation 28–6. The President should convene an interagency task force to plan for modernizing the national environmental data archiving, assimilation, modeling, and distribution system with the goal of designing an integrated Earth environmental data and information system.

The task force should:

- *be comprised of all federal agencies with environmental data collection responsibilities.*
- *create an environmental data management plan that includes specific cost estimates and phasing requirements to ensure timely implementation and appropriate funding.*

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[1] National Oceanic and Atmospheric Administration. *The Nation's Environmental Data: Treasures at Risk*. A Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems. Washington, DC: U.S. Department of Commerce, 2001.
[2] Ibid.
[3] Office of Naval Research and National Science Foundation. *An Information Technology Infrastructure Plan to Advance Ocean Sciences*. Washington, DC, January 2002.
[4] MEDEA. *Special Task Force Report: Scientific Utility of Naval Environmental Data*. McLean, VA: Mitre Corporation, 1995.